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Shedding light on the moon's influence in the reproductive activity of farm animals

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The idea that the Moon influences biological rhythms has long been part of traditional knowledge, and recent scientific evidence increasingly supports its role in regulating animal behavior and physiology. This review aims to assess the influence of the lunar cycle on reproductive activity in farm animals. A total of 40 studies were analyzed, encompassing nine species of agricultural importance, including one study that evaluated four species. The findings reveal that lunar phases can affect ovulation, estrus expression, fertilization, conception rates, embryo development, parturition timing, and semen quality. These effects have been reported in both natural and assisted reproductive settings, including artificial insemination, embryo transfer, and *in vitro* embryo production. Although the strength and direction of lunar influences vary across species and studies, recurring patterns, particularly around the new and full moon phases, suggest that lunar rhythms may modulate reproductive physiology. This review highlights the potential role of the pineal gland and melatonin secretion as mediators of electromagnetic fluctuations associated with the lunar cycle. These subtle environmental cues may influence reproductive functions through neuroendocrine pathways. In conclusion, growing scientific interest in this topic reflects its potential significance in animal biology. Further interdisciplinary research is needed to clarify the physiological mechanisms involved and to explore the practical implications of lunar modulation of reproductive activity in livestock production systems.

KEYWORDS

lunar cycle, reproduction, cattle, goat, sheep, pig, horse, guinea pig

1 Introduction

Over millions of years, animals have developed physiological and behavioral adaptations in response to the moon's influence. As Earth's natural satellite, the moon governs key environmental cycles that have shaped life on the planet, driving the development of reproductive strategies and foraging behaviors attuned to its rhythmic variations (Andreatta and Tessmar-Raible, 2020).

Given its profound ecological impact, it is unsurprising that ancient human cultures recognized the moon's potential role in fertility and reproduction. Myths and legends across civilizations have long linked lunar cycles to biological rhythms (Ritter and Tessmar-Raible, 2024). While many of these beliefs are largely exaggerated, historical observations, such as Aristotle's accounts of marine life responding to lunar phases, suggest that they may have been inspired by genuine biological patterns (Ritter and Tessmar-Raible, 2024).

The moon's influence on living organisms is well documented (reviewed by Zimecki, 2006; Ikegami et al., 2014; Andreatta and Tessmar-Raible, 2020), with its effects most pronounced in marine species. However, research has also demonstrated lunar-driven effects in freshwater fish (Perea et al., 2022), amphibians (Grant et al., 2009; Underhill and Höbel, 2018), reptiles (Escalona et al., 2019; Perea-Brugal et al., 2025), birds (Norevik et al., 2019; Ravache et al., 2020), and mammals (Dixon et al., 2006; Bhatt et al., 2021; Perea M.F. et al., 2024). The mechanisms driving the effects of the lunar phases remain debated and can vary, with potential contributors including nocturnal light levels, gravitational fluctuations, and geomagnetic shifts (Bevington, 2015). Understanding these influences is particularly relevant to animal production, as lunar cycles may act as natural cues for optimizing the reproductive performance of farm animals.

Reproductive success in farm animals, particularly mammals, is crucial, as parturition marks the beginning of a production cycle. This cycle supports the production of food products such as milk and meat, along with dairy and meat by-products, as well other valuable resources like leather and wool in species such as cattle, buffalo, goats, and sheep (Wilson et al., 2005). Additionally, in animals such as horses, whether bred for racing, work, or specialized purposes, reproduction plays a fundamental role in maintaining and improving genetic lines (Khan et al., 2025). Reproductive function is not essential for individual survival and can be disrupted by various environmental factors (Martin et al., 2004; Scaramuzzi and Martin, 2008; Naqvi et al., 2012) that may potentially threaten offspring viability and, consequently, the continuity of the species. Low reproductive efficiency in farm animals decrease productivity and leads to significant economic losses for producers (National Institute of Food and Agriculture, 2024).

Over the past four decades, growing evidence has indicated that the lunar cycle influences key reproductive aspects in farm animals. Some studies indicate that fertility in cattle, sheep, and mares is greater during specific lunar phases (Kollerstrom, 2004; Palacios and Abecia, 2014; Aguirre et al., 2021) with conception rates peaking in the waning phase (Perea et al., 2024a; Pinedo et al., 2025). Additionally, cattle exhibit synchronization of key reproductive events, such as estrus and calving (Roy et al., 1980; Yonezawa et al., 2016), around the new and full moon phases (Aguirre et al., 2021). Similar patterns have been observed in dairy buffaloes (Aranguren-Méndez et al., 2023) and guinea pigs (Perea M.F. et al., 2024).

This review summarizes key findings on this phenomenon across multiple species and highlights a body of scientific evidence that may shed light on the physiological mechanisms underlying lunar-related reproductive variation in farm animals.

2 The lunar cycle and reproduction in mammals

The moon's interaction with Earth generates key cyclical patterns that different organisms can attune to: the lunar month, which spans approximately 29.5 days, the time it takes for the Moon to complete one orbit around the Earth, and the lunar day, lasting 24.8 hours, which is the time required for the Moon to pass over the same location on Earth (Kronfeld-Schor et al., 2013). These cycles influence various environmental factors, including light availability, tidal movements, and geomagnetic variations (Kronfeld-Schor et al., 2013). Additionally, roughly every 14.5 days, the alignment of the Moon, Earth, and Sun results in spring tides around the days of the full and new moon, characterized by higher-than-usual tidal fluctuations. These predictable environmental rhythms serve as reliable cues that animals have evolved to recognize and respond to, enabling them to synchronize their reproductive cycles and other biological processes with optimal environmental conditions (Raible et al., 2017), just as ancient observers first noted millennia ago.

Reproductive activity is essential for mammals, as it ensures the birth of viable offspring, thereby guaranteeing species continuity (Weir and Rowlands, 1973). Reproductive success involves the coordinated interaction of multiple components, including neuroendocrine and endocrine factors, as well as peripheral organs and tissues, that together conform the reproductive axis (hypothalamus-pituitary-ovary-uterus) (Phumsatitpong et al., 2021). Additionally, reproduction encompasses a series of interconnected physiological events, folliculogenesis, follicular dynamics, ovulation, gamete transport, fertilization, maternal recognition of pregnancy, implantation, and placentation, which ultimately lead to parturition and the birth of healthy offspring (Senger, 2012).

However, numerous factors can disrupt these physiological processes, reducing reproductive efficiency or even interrupting reproduction altogether. While the effects of season (Ungerfeld and Bielli, 2012; Goodman and Inskeep, 2015), heat stress (Wolfenson and Roth, 2019), nutrition (Ashworth et al., 2009), and disease (Gilbert, 2019) on animal reproduction have been extensively studied, and the underlying biological mechanisms well described, very little is known about the influence of the lunar cycle on reproductive activity in farm animals. To date, around 40 studies in farm animals have documented this phenomenon, yet no research has specifically investigated its biological foundations.

Given the complexity of mammalian reproduction, identifying the mechanisms by which the lunar cycle influences reproductive processes remains a significant challenge. The interaction between neuroendocrine regulation, environmental cues, and physiological events makes it difficult to isolate the specific pathways through which lunar rhythms may exert their effects.

One of the most plausible mediators linking lunar rhythms to reproductive activity is melatonin, a hormone secreted by the pineal gland in response to darkness (Gelen et al., 2022). Acting as a neuroendocrine signal of night length and seasonal photoperiod, melatonin regulates reproductive activity in seasonal breeders such as sheep, goats, and horses (Chemineau et al., 2008). It modulates the hypothalamic–pituitary axis by influencing the secretion of GnRH, either directly or via neuropeptides like kisspeptin and gonadotropin-inhibitory hormone (Charif and Dorfman, 2025), thus affecting LH and FSH release and downstream ovarian function (Ng et al., 2017).

Melatonin receptors (MT1 and MT2) are also widely expressed in peripheral reproductive tissues (Gao et al., 2022), including the ovaries (Wang et al., 2018), uterus (Dirandeh et al., 2022), and testes (González-Arto et al., 2017), where melatonin can influence steroidogenesis (Duan et al., 2024), follicular growth (Paulino et al., 2022), implantation (Dirandeh et al., 2022), and embryo survival (He et al., 2016).

Moreover, melatonin may also exert effects on reproductive function in non-seasonal species. For instance, in dairy cows, typically considered non-seasonal breeders, melatonin supplementation has been shown to enhance follicular development, corpus luteum function, and uterine blood flow (Abdelnaby and Abo El-Maaty, 2021). Additionally, an increased incidence of double ovulations in dairy cattle was observed during the decreasing day-length period (negative photoperiod) compared to the increasing photoperiod (Lopez-Gatius, 2014). Further evidence for photoperiodic modulation of reproductive function in dairy cattle comes from Hansen and Hauser (1984), who reported that exposure to extended daylight (18 h light/day), shortened the postpartum interval to estrous and conception. These findings imply that even in non-seasonal species like dairy cattle, ovarian and postpartum reproductive activity may be modulated by changes in day length, potentially mediated by melatonin-driven mechanisms.

While some evidence have suggested potential mechanisms underlying lunar influences on reproduction, such as fluctuations in melatonin secretion (Martinez Soriano et al., 2002a; Cajochen et al., 2013; Gerasimov et al., 2014), geomagnetic fluctuations (Olcese, 1990), or other lunar-driven factors (Ikegami et al., 2014), the lack of targeted research leaves many questions unanswered. Understanding these interactions requires a multidisciplinary approach that integrates chronobiology, endocrinology, and reproductive physiology to unravel the underlying biological foundations of this phenomenon.

3 Lunar rhythms and reproductive activity in farm animals

Reports on the influence of the lunar cycle on the reproductive activity of farm animals are limited, yet they provide substantial evidence supporting the existence of this phenomenon. Over the years, its effects have been documented in several domestic species, based on 40 studies, one of which (Abecia et al., 2016) evaluated four different species (Tables 1, 2). Figure 1 shows a marked increase in publications over the past decade (A), and highlights cattle as the most investigated species (B).

These studies were conducted across a broad geographic range, encompassing both the Northern and Southern Hemispheres. The majority were carried out in tropical and subtropical regions of Latin America, such as Venezuela, Brazil, Ecuador, Uruguay, and Mexico, but others were conducted in subtropical and temperate regions of the Northern Hemisphere, including Spain, Switzerland, Turkey, Egypt, and Japan (Table 3). This variation in latitude implies differing photoperiodic environments, which may interact with lunar rhythms and shape reproductive outcomes.

This geographic context is particularly relevant when considering the reproductive strategies of the species studied. While cattle, pigs, poultry, and guinea pigs are polyestrous and reproduce year-round, species such as sheep, goats, mares, and buffaloes exhibit seasonal reproductive patterns modulated primarily by changes in day length (Malpaux et al., 2001; Chemineau et al., 2008). In equatorial regions, where day–night variation is minimal throughout the year, the influence of lunar cues—such as geomagnetic fluctuations or melatonin-driven hormonal changes—may be more easily perceived. In contrast, in higher latitudes where photoperiod exerts a dominant role, subtle lunar effects may be masked or modulated. These biological and environmental interactions could contribute to the variation observed among studies and should be considered when interpreting lunar-related reproductive patterns across species and locations.

In this review, all studies involving seasonal species were conducted during the breeding season, except for the report on buffaloes, which included both breeding and non-breeding periods.

Given the diversity of approaches used to define lunar phases across studies, Tables 1, 2 report the specific classification system applied in each case. To support interpretation, a schematic overview of the lunar cycle and common subdivisions is provided in Figure 2.

3.1 Cattle

3.1.1 Fertility

One of the most intriguing aspects observed in female bovines is the influence of the lunar cycle on fertility. Fertility reflects the interaction of biological and environmental factors that can enhance, compromise, or hinder fertilization and early embryonic development (Perea and González-Stagnaro, 2010). Fertility is the outcome of a complex process influenced by factors inherent to the cow, such as breed (Perea-Ganchou et al., 2005), age, as well as by the fertilizing capacity of the bull's semen (De Kruif, 1978) and environmental factors, including season (Perea et al., 2006), nutritional status (Bisinotto et al., 2012), and disease presence (Sheldon et al., 2009). As detailed below, five independent studies conducted in different regions and cattle breeds found that fertility, measured by conception rate, was greater during specific periods of the lunar cycle.

One of these studies analyzed 5,869 reproductive records from dual-purpose tropical crossbred cows (*Bos indicus* × *Bos taurus*) in two distinct agroecological areas of the Lake Maracaibo basin, Venezuela (Aguirre et al., 2021). The variation in conception rate at first service was assessed by dividing the lunar cycle (29.52 days) into 30 periods of approximately one day each. While a significant fluctuation in this reproductive index was observed throughout the lunar cycle (Figure 3), a clear increasing trend emerged from the

TABLE 1 Summary of studies evaluating the influence of the lunar cycle on reproductive traits in bovines.

Reproductive traits evaluated	Sample size (n)	Lunar cycle division	Main findings	Reference
Estrous and conception frequency	64	Four quarters	Estrus and conception showed four distinct peaks at approximately 7-day intervals within the lunar cycle	Roy et al., 1980
Number of artificial inseminations	13,493	New moon, full moon and other days of month cycle	20% of AIs occurred during FM and NM, while 80% took place on the remaining days of the lunar month	Subramaniam et al., 1991
Spontaneous births	428	Eight phases	Increased effects in multiparous cow. No effects in nulliparous cows	Yonezawa et al., 2016
Offspring sex ratio	24,268	Four phases	No effect of the lunar cycle on the sex ratio was observed	Abecia et al., 2016
Gestation length and daily birth rate in cows	2,050,532	29,5 days	Highest daily birth rate detected on day 4 after new moon (+1.9%) and the lowest on day 20 (−2.1%).	Ammann et al., 2016
Conception rates in dairy and beef cattle	1,481	Four phases	Full moon greater conception than new moon.	Popescu et al., 2017
Frequency of calving	13,206	Two and four phases	No difference found in conception rates in the different lunar phases.	Mateos and Rodríguez-Ledesma, 2017
Frequencies of daily and preterm calving	41,116	Eight phases	No effect of lunar cycle in daily calving frequency. Lunar phases not associated with occurrence of preterm calving.	Sasaki et al., 2019
First service conception rate, frequencies of calving, first postpartum estrus and pregnancies	5,869	Thirty periods of 0.984 days each. Four phases.	First service conception greater in waning than crescent phase. Frequencies of calving, first estrus and pregnancy greater at full moon and new moon	Aguirre et al., 2021
Sperm characteristics	960	Four phases	Increased in the sperm motility and metabolic activity in the new moon to the max activity in full moon	Shestakov et al., 2021
Estrous and calving frequency, pregnancy rate and offspring sex	580	Four quarters	FM reduced estrus occurrence. No significant effect on pregnancy, calving, or offspring sex	Muñoz-García et al., 2023
Oocyte quality, rate of cleavage, and blastocyst yield	7,805 oocytes	Two phases and four quarters	The lunar cycle influenced oocyte quality, cleavage rate, and blastocyst yield, with greater numbers in the waning than in the crescent phase	Hernández-Fonseca et al., 2023
Pregnancy rate and pregnancy losses following transfer of bovine embryos produced *in vitro*	12,245	Thirty periods of 0.984 days each; two phases	The lunar cycle influenced pregnancy rate following the transfer of fresh *in vitro*-produced embryos. Pregnancy losses showed large variability throughout the lunar cycle	Perea et al., 2024a
Calving frequency, gestation length, birth weight, and calf sex in artificial inseminated cows	121,276	Thirty periods of 0.984 days each	Calving distribution peak at 2 days around the new and full moon. Moon cycle influenced gestation length and calf birth weight. No association between the lunar cycle and the sex of calves	Perea et al., 2024b
Oocyte recovery, cleavage rate, blastocyst rate, transferable embryos	101,548 oocytes	Thirty periods of 0.98 days each (crescent = 1–15; waning = 16–30)	Significant variation across lunar cycle; better outcomes in the second half of waning phase	Hernández-Fonseca et al., 2024
Association of lunar cycle with pregnancy at first artificial insemination	24,983	Four and eight phases	A small but significant association was observed between the lunar cycle and pregnancy at first AI	Pinedo et al., 2025
Conception rate in Holstein heifers	21,527	Thirty periods of 0.984 days each and waxing/waning phases	Conception rates varied by lunar day and were significantly higher during the waxing phase. Lunar influence was modulated by region, season, and age	Perea et al., 2025a
Conception rate in lactating Holstein cows	72,006	Thirty periods of 0.984 days each and waxing/waning phases	Conception rates were higher during the waxing phase. Lunar effect varied significantly with days in milk, age, and year	Perea et al., 2025b

TABLE 2 Summary of studies evaluating the influence of the lunar cycle on reproductive traits in various livestock species.

Species	Reproductive traits evaluated	Sample size (n)	Lunar cycle division	Main findings	Reference
Horses	Frequency of mating and conceptions at first mating	2,420	29 lunar days	Greater conception rate between days 15–19 of the lunar month.	Kollerstrom and Power, 2000
	Frequency of coverings and conception rate	3,428	29 lunar days	Peaks of coverings (estrus) and conception rate greater on or just after full moon.	Kollerstrom, 2004
	Sex ration at birth	65,535	Four phases	No influence in sex ratio of the offspring	Aguilar et al, 2014
	Time of ovulation, incidence of births, female: male ratio	356	Four phases	Higher incidence of males births on the waning phase was observed compared to the new and crescent phase	Marinho et al, 2015
Sheep	Estrous and conception distribution, number of inseminations per conception, lambing rate	9,650	Four phases	Lunar phase affected distribution of estruses and conceptions, number of inseminations per conception, and lambing rate	Horak and Potucek, 1978
	Frequency of lamb births	68,127	Four periods	Although no significant differences were detected among lunar phases, a slightly greater percentage of births occurred during NM	Palacios and Abecia, 2011
	Birth frequency, litter weight and size, perinatal mortality	136	New moon, full moon and other days of lunar cycle	Moon phases affected birth frequency, litter weight and size, and mortality at birth	El-Darawany et al, 2014
	Fertility, prolificacy and fecundity in sheep after artificial insemination	383	Four phases	Moon cycle affected fertility and fecundity, but not prolificacy	Palacios and Abecia, 2014
	Offspring sex ratio	51,407	Four phases	No effect of the lunar cycle on the sex ratio was observed	Abecia et al., 2016
Goats	Offspring sex ratio	3,150	Four phases	No effect of the lunar cycle on the sex ratio was observed	Abecia et al., 2016
	Body measurements, age at puberty, vaginal mucus characteristics, serum progesterone concentrations	36	New moon, full moon and other days of lunar cycle	Lunar phase at birth effects on body measurements, age of puberty and progesterone concentrations	El-Darawany et al, 2021
	Age of puberty, testicular morphology, testosterone concentration, and semen quality	33	New moon, full moon and other days of lunar cycle	Bucks born during the FM reached puberty earlier and had greater testosterone concentrations, ejaculate volume, sperm concentration, mass motility, and percentage of live sperm compared to those born during the NL and OL phases	El-Tarabany et al., 2021
	Gestation length and parturition time	624	Eight phases. Dark and bright nights	44% of births occurred during FM and waning gibbous. Gestation was shorter in goats giving birth during bright nights than in dark nights and FQ, but similar to LQ	Erduran, 2025a
	Age at conception, parturition timing, gestation length, pregnancy and abortion rates	217	Four categories (bright nights, dark nights, FQ, LQ	Higher frequency of conceptions and parturitions during dark nights; gestation longer in dark vs. bright nights; no effect on pregnancy or abortion rates	Erduran, 2025b
Buffalo	Reproductive performance, calving frequency	3,510	30 periods (0.98 days each)	Calving-to-conception interval was shorter in the waning phase. Calving frequency greater around the new moon and full moon	Aranguren-Méndez et al., 2023
Camels	Spontaneous onset of labor	415	Eight phases	Lunar cycle did not affect distribution of births. Male calves were more likely to be born during brighter lunar night	Iglesias Pastrana et al, 2023
Pigs	Offspring sex ratio	240	Four phases	No effect of the lunar cycle on the sex ratio was observed. The proportion of males among piglets conceived during the waxing phase was significantly greater than 1:1	Abecia et al., 2016
	Semen characteristics	4,149	Four phases	Moon phase affected ejaculate volume and number of semen doses. Effects observed weeks after lunar phase exposure	Chinchilla-Vargas et al, 2018

(Continued)

TABLE 2 Continued

Species	Reproductive traits evaluated	Sample size (n)	Lunar cycle division	Main findings	Reference
	Reproductive and productive traits	12,719	Eight phases	Lunar cycles influenced several reproductive traits	Pichazaca and Zhirzhán, 2023
	Semen characteristics	3,315	Eight phases	The lunar cycle affected sperm concentration, total number of spermatozoa and number of insemination doses	Pesántez, 2025
Guinea pigs	Offspring sex ratio, litter size, number of weaned guinea pigs, individual and litter weaning weight, birth frequency and mortality	7,352	Eight phases	The lunar cycle influenced litter size, mortality, number of pups weaned and individual and litter weaning weights.	Perea M.F. et al, 2024
	Serum progesterone and estradiol concentrations and follicular count	80	Four phases	Lunar cycle influenced serum progesterone and estradiol concentrations, and number and percentage of primordial and large antral follicle	Perea et al, 2024c
Poultry	Post-thawing quality of avian sperm	108	Eight phases	Sperm motility, viability, and membrane integrity were influenced by the lunar phase	Díaz Ruiz et al, 2024

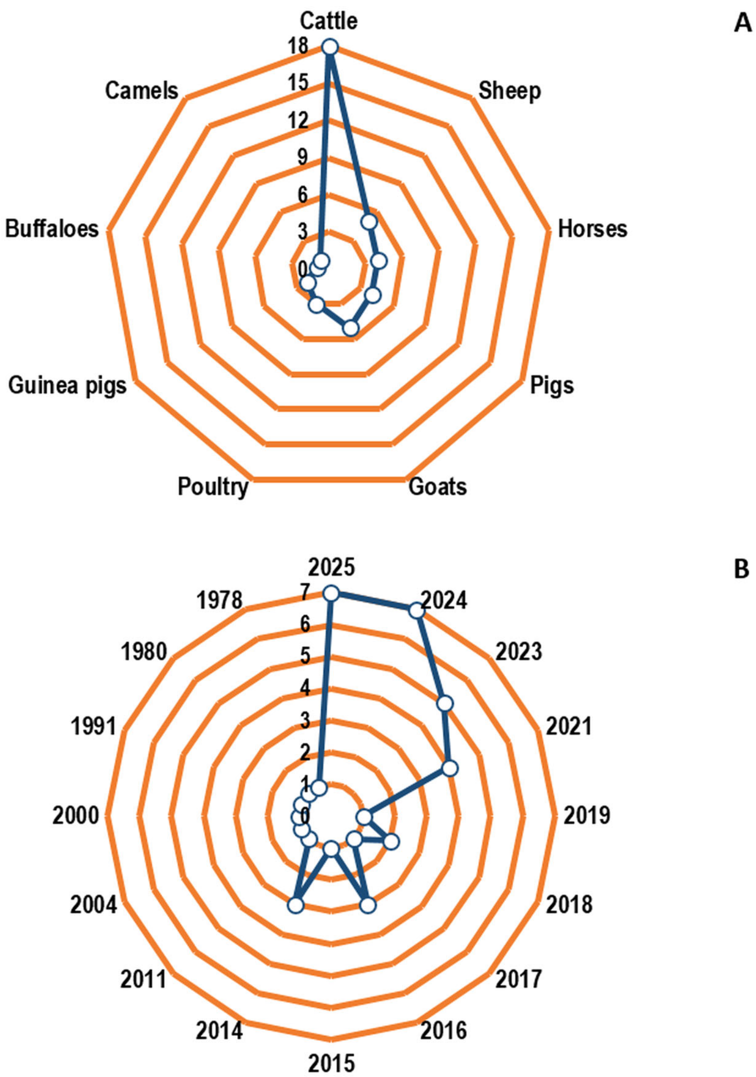

FIGURE 1
Number of scientific publications addressing the influence of the lunar cycle on reproductive activity in farm animals. **(A)** Distribution of studies by species, with cattle representing the most extensively investigated species. **(B)** Temporal distribution of publications, highlighting a notable increase in scientific interest over the past decade.

TABLE 3 Geographic, environmental, and reproductive context of studies evaluating the influence of the lunar cycle on reproductive activity in farm animals.

Reproductive Strategy/Species	Country/Region	Hemisphere	Climate Zone	Reproductive Method	Reference
Continuous					
Cattle	England	Northern	Temperate	ART (AI)	Roy et al., 1980
	India	Northern	Tropical	ART (AI)	Subramaniam et al., 1991
	Japan	Northern	Temperate	ART (AI)	Yonezawa et al., 2016
	Spain	Northern	Subtropical	NA	Abecia et al., 2016
	Switzerland	Northern	Temperate	NA	Ammann et al., 2016
	Rumania	Northern	Temperate	NA	Popescu et al., 2017
	Spain	Northern	Subtropical	NA	Mateos and Rodríguez-Ledesma, 2017
	Japan	Northern	Temperate	NA	Sasaki et al., 2019
	Venezuela	Northern	Tropical	ART (AI)	Aguirre et al., 2021
	Russia	Northern	Temperate	ART (SCP)	Shestakov et al., 2021
	Mexico	Northern	Tropical	ART (ES and AI)	Muñoz-García et al., 2023
	Brazil	Southern	Tropical	ART (IVP)	Hernández-Fonseca et al., 2023
	Brazil	Southern	Tropical	ART (ET)	Perea et al., 2024a
	Venezuela	Northern	Tropical	ART (AI)	Perea et al., 2024b
	Brazil	Southern	Tropical	ART (IVP)	Hernández-Fonseca et al., 2024
	United States	Northern	Temperate	ART (AI)	Pinedo et al., 2025
	Uruguay	Southern	Subtropical	ART (AI)	Perea et al., 2025a
	Uruguay	Southern	Subtropical	ART (ES, TAI, AI)	Perea et al., 2025b
Pigs	Spain	Northern	Subtropical	NA	Abecia et al., 2016
	United States	Northern	Temperate	ART (SCP)	Chinchilla-Vargas et al, 2018
	Venezuela	Northern	Tropical	ART (AI)	Pichazaca and Zhirzhán, 2023
	Venezuela	Northern	Tropical	ART (SCP)	Pesántez, 2025
Guinea pigs	Ecuador	Southern	Tropical	NM	Perea M.F. et al, 2024
	Ecuador	Southern	Tropical	NA	Perea et al, 2024c
Poultry	Spain	Northern	Subtropical	ART (SCP)	Díaz Ruiz et al, 2024
	Ecuador	Southern	Tropical	NM	Fárez and Quezada, 2024
	Ecuador	Southern	Tropical	NA	Sinchi and Sisalima, 2025
Seasonal					
Horses	England	Northern	Temperate	NM	Kollerstrom and Power, 2000
	England	Northern	Temperate	NM	Kollerstrom, 2004
	Argentina	Southern	Subtropical	NM	Aguilar et al, 2014
	Brazil	Southern	Tropical	NM, ART (AI, ET)	Marinho et al, 2015
Sheep	Czechoslovakia	Northern	Temperate	ART (AI)	Horak et al., 1978
	Spain	Northern	Subtropical	NA	Palacios and Abecia, 2011
	Egypt	Northern	Subtropical	NA	El-Darawany et al, 2014
	Spain	Northern	Subtropical	ART (AI)	Palacios and Abecia, 2014

(Continued)

TABLE 3 Continued

Reproductive Strategy/Species	Country/Region	Hemisphere	Climate Zone	Reproductive Method	Reference
Seasonal					
	Spain	Northern	Subtropical	NA	Abecia et al., 2016
Goats	Spain	Northern	Subtropical	NA	Abecia et al., 2016
	Egypt	Northern	Subtropical	NA	El-Darawany et al., 2021
	Egypt	Northern	Subtropical	ART (SCP)	El-Tarabany et al., 2021
	Turkey	Northern	Temperate	NM	Erduran, 2025a
	Turkey	Northern	Temperate	NM	Erduran, 2025b
Buffalo *	Venezuela	Northern	Tropical	ART (ES, TAI, AI)	Aranguren-Méndez et al., 2023
Camels	Spain (Canarias)	Northern	Subtropical	NA	Iglesias Pastrana et al, 2023

ART, assisted reproductive technology; AI, artificial insemination; NA, information not available; ES, estrous synchronization; SCP, semen collection and processing; IVP, *in vitro* embryo production; TAI, timed artificial insemination; NM, natural mating. *The study covered the whole year, including both the breeding and non-breeding seasons. Climatic zones were classified according to the Köppen–Geiger system (Peel et al., 2007).

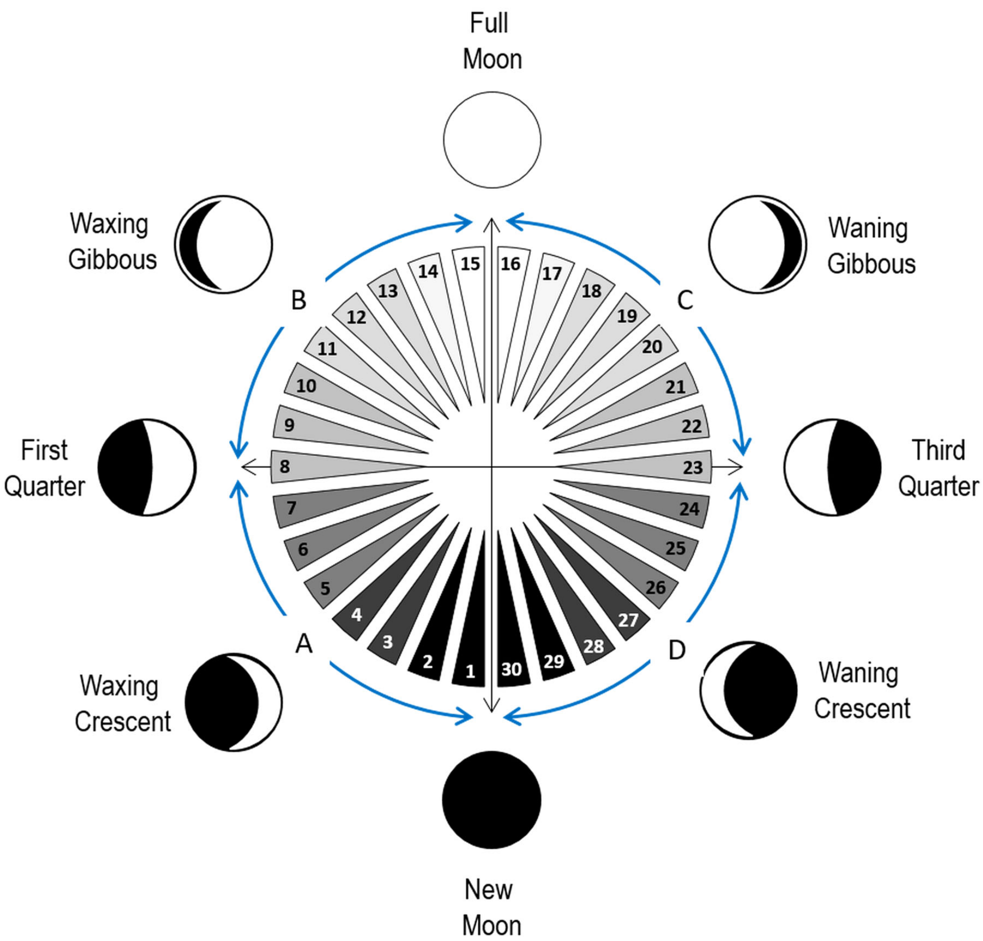

FIGURE 2
Divisions of the lunar cycle used across different studies. **(A–D)** four-quarter division of the cycle **(A)** new moon to first quarter; **(B)** first quarter to full moon; **(C)** full moon to third quarter; **(D)** third quarter to new moon, each lasting approximately 7.4 days. 1–15 and 16-30: division into waxing (crescent) and waning phases (~14.7 days each). 1-30, division into 30 lunar days (~0.98 days each). Periods 1–8, common subdivision of the lunar cycle into eight intervals (~3.7 days each): (1) new moon to waxing crescent, (2) waxing crescent to first quarter, (3) first quarter to waxing gibbous, (4) waxing gibbous to full moon, (5) full moon to waning gibbous, (6) waning gibbous to last quarter, (7) last quarter to waning crescent, and (8) waning crescent to new moon. Alternatively, based on lunar illumination, the cycle can also be divided into eight phases (~3.7 days each): new moon (0–12.5% illumination; waxing or waning), waxing crescent (12.5–37.5%; waxing), first quarter (37.5–62.5%; waxing), waxing gibbous (62.5–87.5%; waxing), full moon (87.5–100% illumination; waxing and waning), waning gibbous (87.5–62.5%; waning), last quarter (62.5–37.5%; waning), and waning crescent (37.5–12.5%; waning).

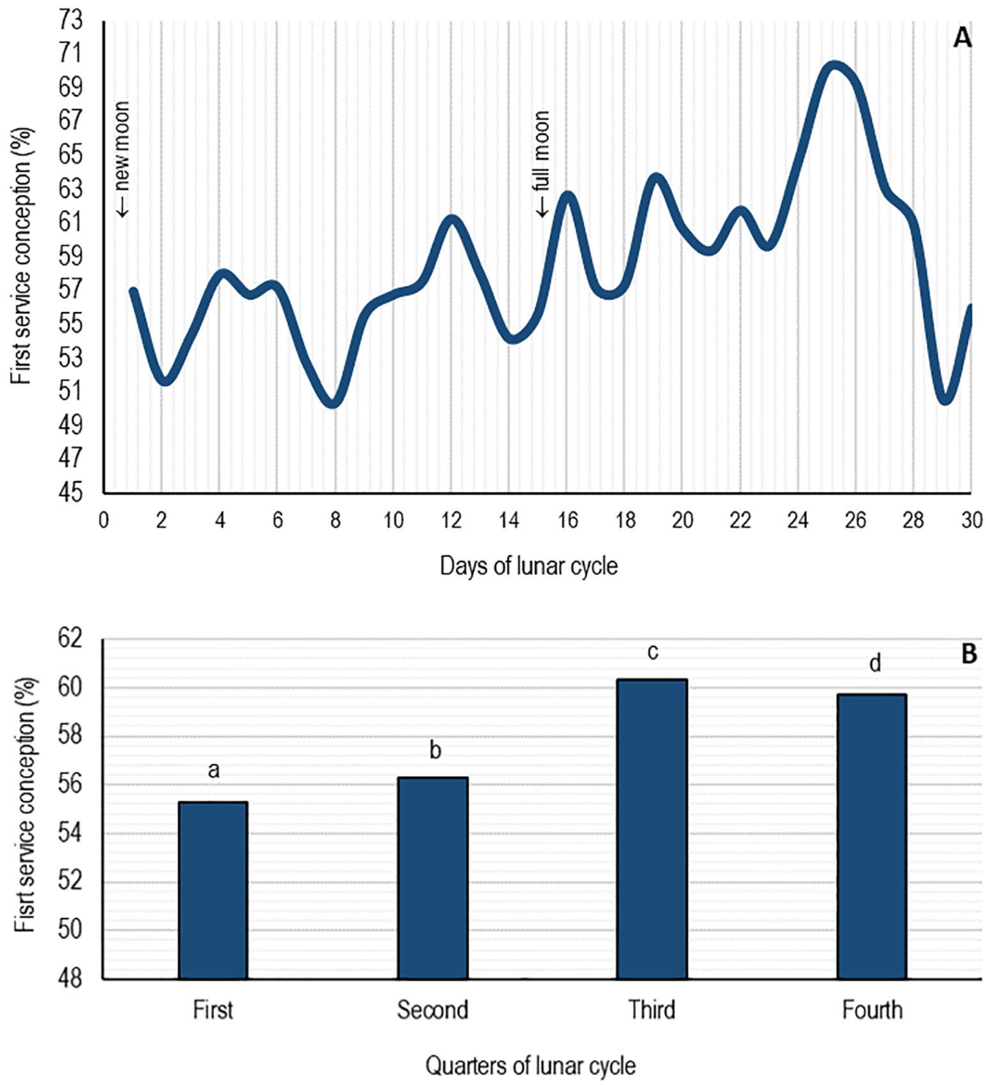

FIGURE 3
Influence of lunar cycle on first service conception rate in crossbreed Brahman cows (n = 5869). **(A)** Variation of first service conception throughout lunar cycle (P = 0.0366 for main effect of lunar cycle in the logistic regression model). **(B)** The percentages of first service conception according to quarters of lunar cycle ($^{a-c}$ P = 0.0111; $^{a-d}$ P = 0.0190; $^{b-c}$ P = 0.0398; $^{b-d}$ P = 0.0699). Adapted with permission from Aguirre et al. (2021). *Lunar cycle influences reproductive performance of crossbred Brahman cows under tropical conditions*. Journal of Biological Rhythms, 36(2):163-171. SAGE Publications (License Number 6004421190291).

new moon to the last quarter (LQ), peaking on days 25 and 26 of the cycle. As shown in Figure 3, when the lunar cycle was divided into four quarters, the first service conception rate was significantly greater during the third and fourth quarters compared to the first two.

In a study conducted on Holstein cows (n = 24,983) at an organic farm in northern Colorado, USA, an association was observed between conception rate and the lunar cycle (Pinedo et al., 2025). The lunar cycle was categorized in two ways: (1) four equal phases—new moon to first quarter, first quarter to full moon, full moon to third quarter, and third quarter to new moon; and (2) eight phases—new moon, first quarter, full moon, and third quarter (each lasting one day), along with waxing crescent, waxing gibbous, waning gibbous, and waning crescent (each lasting four days). The probability of pregnancy was significantly greater in the third quarter than during the new moon in both primiparous and multiparous cows. When considering the eight-phase categorization, a significant effect was observed only in primiparous cows, probability of pregnancy was greater during the first and third quarters than during the new moon. Overall, conception rates tended to be greater during the waning phase than during the waxing phase.

In a tropical region of southern Brazil, a study analyzed 12,245 transfers of *in vitro*-produced (*Holstein* × *Gyr*) embryos (Perea et al., 2024a). The lunar cycle, divided into 30 periods of approximately 0.98 days each, significantly influenced conception rates at both 30 and 60 days post-transfer. Conception rates fluctuated considerably throughout the lunar cycle, with more frequent and pronounced peaks occurring during the waning phase compared to the crescent phase. The highest peak of conception rate was observed on day 27 of the lunar cycle.

Notably, the effect of the lunar cycle on conception rates was highly significant when analyzed in relation to both the day of oocyte collection and the day of embryo transfer.

A study conducted in Romania analyzed 1,481 bovine pregnancies across dairy and beef farms to assess the influence of lunar phases on conception rates (Popescu et al., 2017). While the study found some differences in conception rates between lunar phases, the effects were relatively small and varied depending on the number of animals included in each analysis. Notably, conception rates were slightly higher during the full moon compared to the new moon, and farms using hormonal synchronization for estrus detection exhibited a clearer relationship between lunar phases and fertility outcomes. However, given the variability in results across different farms and breeds, the study concluded that the influence of the lunar cycle on bovine conception remains uncertain and requires further investigation to determine its biological and practical significance.

Fertility is a multifactorial trait shaped by the interaction of numerous biological mechanisms and external factors (Perea-Ganchou and González-Stagnaro, 2005). It is therefore reasonable to expect that breed, geographic location, and environmental or management conditions could modulate the influence of lunar rhythms on reproductive performance. This hypothesis is supported by two recent studies conducted in Holstein cattle herds from the Southern region of Latin America. One study, involving over 21,000 heifers, demonstrated that first-service fertility was significantly influenced by the lunar cycle, with marked variation depending on season, region, and year. Notably, conception rates were higher during the waxing phase, especially during spring (Perea et al., 2025a). A second study, conducted in over 72,000 lactating Holstein cows, found similar results: increased fertility during the waxing phase, which varied significantly across days of the lunar cycle, with this effect being modulated by days in milk, age, season, and year (Perea et al., 2025b).

These findings emphasize that the reproductive effects associated with lunar phases are not universally expressed in the same way, but rather emerge through complex interactions with physiological, environmental, and temporal variables. Identifying the specific conditions under which lunar cues exert measurable effects on reproductive success will be key to understanding their biological basis and practical implications in dairy herd management.

3.1.2 Oocyte quality and *in vitro* embryo production

The quality of oocytes collected from donor cows varies depending on numerous factors (Camargo et al., 2006). In general, higher oocyte quality is associated with a greater proportion of oocytes that mature, undergo fertilization, and develop to the blastocyst stage after six days of *in vitro* culture (Lonergan and Fair, 2014). In line with the findings on fertility, two studies conducted in Brazil demonstrated that the lunar cycle influences *in vitro* embryo production, which was greater during the waning rather than the waxing lunar phase.

In an *in vitro* fertilization laboratory in Minas Gerais, Brazil, a total of 7,805 oocytes were collected from 374 donor cows (Hernández-Fonseca et al., 2023). These oocytes were matured and fertilized *in vitro*, then cultured for six days. The study found that both the number and proportion of viable oocytes, cleaved embryos, and blastocysts were significantly greater during the waning phase compared to the crescent phase of the lunar cycle. Furthermore, when the lunar cycle was divided into four quarters of equal length, blastocyst production was significantly greater in the fourth quarter compared to the other three (Table 4).

In an *in vitro* fertilization laboratory located in the tropical southern region of Brazil, a large-scale study analyzed 101,548 oocytes collected from 6,714 ovum pick-up sessions involving Gyr donor cows (Hernández-Fonseca et al., 2024). Statistical analysis revealed a significant effect of the lunar cycle on the outcomes of *in vitro* embryo production. Notable variations were observed in the number of viable oocytes (ranging from 12.1 to 19.2), cleavage rate (56.4% to 79.4%), blastocyst rate (21% to 31.8%), and transferable embryo rate (17.2% to 26.6%). Moreover, both blastocyst and transferable embryo rates exhibited a clear increasing trend throughout the lunar cycle, with more frequent and pronounced peaks occurring during the waning phase compared to the waxing phase.

Taken together, the findings of these two studies reinforce and expand upon previous evidence of the lunar cycle's influence on

TABLE 4 Number and proportion of viable oocytes, cleaved embryos and blastocysts according to quarters of lunar cycle.

Variable	Quarters of lunar cycle			
	First	Second	Third	Fourth
Number				
Viable oocytes	15.9 ± 1.7	13.2 ± 1.1^{a}	15.6 ± 1.8	18.4 ± 2.0^{b}
Cleaved embryos	11.1 ± 1.4	9.9 ± 0.9^{b}	12.8 ± 1.4	14.5 ± 1.6^{c}
Blastocysts	4.3 ± 0.7^{a}	4.3 ± 0.5^{a}	5.1 ± 0.8	6.4 ± 0.8^{b}
Proportion				
Viable oocytes ^{A}				
%	74.2^{1}	65.2^{2}	73.53^{3}	71.1^{4}
n	1581/2129	1727/2650	1326/1804	869/1222
Cleaved embryos ^{B}				
%	75.0^{4}	78.3^{5}	79.0^{6}	77.3^{7}
n	1188/1584	1370/1749	1036/1312	672/869
Blastocysts ^{C}				
%	29.8^{7}	33.6^{8}	32.5^{9}	37.0^{10}
n	472/1581	581/1727	424/1304	322/869

Main effect of lunar cycle in the logistic regression model: ^{A}P<0.0001; ^{B}P=0.0098; ^{C}P=0.0029. Values with different superscript differ: $^{a\text{-}b}$P<0.05; $^{b\text{-}c}$P<0.01; $^{1\text{-}2;\ 2\text{-}3;\ 2.4;\ 4\text{-}5;\ 4\text{-}6;\ 4\text{-}7;\ 7\text{-}8;\ 7\text{-}9;\ 7\text{–}10}$P<0.01; $^{7\text{–}8}$P<0.05.

First quarter: from new moon to first quarter; Second quarter: from first quarter to full moon; Third quarter: from full moon to third quarter; Fourth quarter from third quarter to new moon.

Adapted from Table 1 in Hernández-Fonseca et al. (2023). *Effect of lunar cycle on oocyte quality, rate of cleavage, and in vitro blastocyst production in cows.* Reproduction, Fertility and Development. 35(2):129-130. https://doi.org/10.1071/RDv35n2Ab10.

reproductive outcomes in cattle. Notably, this body of evidence confirms that the lunar cycle affects not only conception rates in cows showing spontaneous estrus and subjected to conventional artificial insemination (Aguirre et al., 2021; Pinedo et al., 2025), but also in cows undergoing hormonal synchronization protocols for fixed-time artificial insemination (Perea et al., 2024a). Furthermore, the lunar phase also appears to influence oocyte quality in donor cows, as well as subsequent outcomes such as blastocyst yield and the proportion of transferable embryos (Hernández-Fonseca et al., 2023; 2024).

Given that *in vitro* embryo production is highly sensitive to environmental and technical factors (Camargo et al., 2006), strategically timing oocyte collection during the second week of the luteal phase, could be a useful approach in commercial embryo production programs seeking to optimize the output of high-quality embryos. These findings offer promising insights for enhancing the efficiency of reproductive biotechnologies in cattle.

3.1.3 Patterns in reproductive events

Several studies analyzing extensive datasets have demonstrated an association between the lunar cycle and the occurrence of postpartum reproductive events, including estrus, pregnancy, and calvings.

A study conducted in India analyzed the distribution of 13,493 artificial inseminations (AI) across different phases of the lunar cycle (Subramaniam et al., 1991). The cycle was categorized into three groups: inseminations performed during the new moon (NM), full moon (FM), and all other days (OD) of the lunar month. A total of 1,336 and 1,356 cows were inseminated on the days of the NM and FM, respectively, while 10,801 AI occurred on the remaining days of the lunar cycle. This distribution indicates that approximately 9.9% of all inseminations took place on each of the NM and FM days, whereas only 2.8% occurred on any other given day of the cycle.

In the western region of Venezuela, a study analyzed 5,869 reproductive records from crossbred Brahman cows to assess the influence of the lunar cycle on key postpartum reproductive events (Aguirre et al., 2021). The lunar cycle, divided into 30 periods of approximately 0.98 days each, significantly affected the distribution of calving, first postpartum estrus, and pregnancies. These reproductive events followed a similar pattern, with the highest frequencies occurring around the new moon and full moon (~1 day around the moon reaches 0% or 100% luminosity, respectively), reaching approximately 16–18% in each case. In contrast, during the remaining 26 days of the lunar cycle, the frequency of these events averaged only ~2.5% per day. Moreover, a highly significant positive correlation was observed between the frequencies of calving, first postpartum estrus, and pregnancy (0.77, 0.91, and 0.80, respectively), indicating a strong temporal relationship among these reproductive events.

In the same region of Venezuela, a much larger dataset (n = 121,276) was analyzed, revealing a consistent relationship between the lunar cycle (divided into 30 days) and the distribution of births (Perea et al., 2024b). Regardless of parity (primiparous or multiparous cows) and gestation length (preterm, full-term, or post-term), the number of calving was significantly greater, well above the population average, around the new moon and full moon (~1 days before and after moon reaches 0% or 100% luminosity, respectively). Additionally, the lunar cycle influenced gestation length in multiparous and total cows, though not in primiparous cows, with differences of less than one day. Moreover, calf birth weight was significantly greater around the new moon compared to the full moon and the remaining days of the lunar cycle.

Interestingly, despite a smaller dataset (n = 428), Yonezawa et al. (2016) reported findings in Holstein cows that align with those of the previously reviewed studies. The spontaneous frequency of full-term births increased steadily from the new moon to the full moon and then declined until the waning crescent phase, with the lunar cycle divided into eight phases. A statistically significant peak in calving frequency was observed between the waxing gibbous and full moon phases, compared to the period spanning the last quarter and waning crescent phases. These differences were clearly evident in multiparous cows but were not significant in nulliparous cows.

Other studies have found no relationship between the lunar cycle and calving frequency, or the observed association was not particularly pronounced. An analysis of 2,091,159 cattle records from various breeds in Switzerland revealed that, although the daily birth rate was unevenly distributed throughout the lunar cycle, no clear pattern could be identified (Ammann et al., 2016). Compared to the average birth rate across the lunar cycle (divided into 29 days), the highest daily birth rate was observed on day 4 after the new moon (+1.9%), while the lowest occurred on day 20 (−2.1%).

Similarly, a study examining the relationship between the lunar cycle, divided into eight phases, and the frequency of preterm births (n = 41,116) in Japanese Black cows found no significant influence of the lunar cycle on this reproductive event (Sasaki et al., 2019). In Mexico, an analysis of 580 reproductive records in crossbred cows found no association between the lunar cycle (split into four quarters) and calving frequency (Muñoz-García et al., 2023). Likewise, when assessing the influence of the lunar cycle (divided into two and four phases) on calf birth frequency (n = 13,206) in extensive production systems in Extremadura, Spain, results indicated that birth distribution remained uniform across lunar phases (Mateos and Rodríguez-Ledesma, 2018).

The lunar cycle appears to influence the timing of critical postpartum reproductive events in cattle. Several studies have consistently reported a bimodal distribution in the frequency of calving, first postpartum estrus, and subsequent conception, with distinct peaks occurring around the new moon and full moon phases (Subramaniam et al., 1991; Yonezawa et al., 2016; Aguirre et al., 2021; Aranguren-Méndez et al., 2023; Perea et al., 2024b). The recurrence of this pattern across diverse herds and geographical regions suggests the existence of a biological mechanism capable of synchronizing reproductive activity with lunar rhythms.

However, large-scale evaluations have produced mixed results. While some datasets support this bimodal trend, others have failed to detect any consistent relationship between the lunar cycle and reproductive events (Ammann et al., 2016; Sasaki et al., 2019; Mateos and Rodríguez-Ledesma, 2018; Muñoz-García et al., 2023). One likely source of this inconsistency is methodological:

studies that classify the lunar cycle into few phases may lack the resolution needed to detect subtle, time-dependent variations. In contrast, analyses using more detailed categorization of the lunar cycle, such as daily divisions or 30-interval schemes, have been more successful in revealing cyclical fluctuations. This highlights not only the complexity of lunar influences on reproductive physiology but also the importance of analytical sensitivity in detecting them.

Moreover, the potential modulation of lunar effects by environmental, geographic, or management-related factors cannot be ruled out. Future research should aim to disentangle these interacting influences to better characterize the biological relevance and practical implications of lunar timing in livestock reproductive management.

3.1.4 Semen quality in bulls

Only one study in cattle has addressed the influence of the lunar cycle on seminal parameters. A study conducted in Russia evaluated the effect of lunar phases on seminal characteristics in bulls from different breeds and genetic lines (Shestakov et al., 2021). A total of 960 ejaculates from 18 bulls were analyzed, with approximately 240 ejaculates recorded during each lunar phase. The lunar cycle was divided into four classical phases: NM, FQ, FM, and LQ. Significant differences were observed among phases, with greater values of sperm motility, ejaculate volume, and sperm concentration during the full moon phase. These traits were lowest around the NM. Interestingly, bulls from different lines exhibited varying degrees of sensitivity to lunar phase changes, with animals of the Montvik Chieftain line showing the greatest responsiveness, while those of the Siling Traijune Rokita line appeared less affected. The findings suggest that the lunar cycle may influence seminal traits in bulls and that genetic background could modulate this variation.

3.2 Horses

3.2.1 Conception rate

Two studies on thoroughbred mares conducted in Newmarket, UK, explored the relationship between the lunar cycle, the frequency of mating, and the probability of conception. Additionally, two other studies examining the influence of the moon on foal sex ratio will be discussed in a later section.

In the first study (n = 4,880 matings), mating data were grouped according to the 29-day lunar cycle, where day 1 corresponded to the NM and Day 15 to the FM (Kollerstrom and Power, 2000). The days were divided into 5-day intervals to analyze the lunar phases, with a particular focus on the periods around the FM and NM. An increase in conceptions was observed from the end of the FQ (day 6) until the FM, reaching peak values between days 15 and 19, before declining until day 25 of the lunar cycle. Additionally, the conception rate at the first mating was highest on days near the FM, with a notable decrease around the FQ and near day 25 of the lunar cycle.

In the second study, a total of 3,428 matings in mares younger than 12 years were analyzed (Kollerstrom, 2004). As in the previous study, the lunar cycle was split into 29 days (day 1: NM, Day 15: FM) using the lunar day number method, allowing for a more precise analysis of the relationship between lunar phases and matings. Additionally, an analysis based on the Sun-Moon angle was applied to correlate lunar days with fertility. The results were consistent with those of the previous study: mare estrus, indicated by mating dates, showed a pronounced minimum around the FQ, peaking near the FM and remaining elevated for approximately one week afterward. Fertility increased by up to 29% around the FM, followed by a notable decline toward the FQ.

Furthermore, this study evaluated the effect of lunar nodes, which are two points in space where the Moon's orbit crosses the plane of the Earth's orbit around the Sun. One of these points is the ascending node (when the Moon moves from the Southern to the Northern Hemisphere), while the other is the descending node (when the Moon moves from the Northern to the Southern Hemisphere). It was observed that fertility was higher when the Sun was farther from the lunar nodes, suggesting that the Moon's latitude during the lunar cycle could influence mare fertility.

The findings from both studies on mares reveal a consistent association between the lunar cycle and reproductive parameters, particularly estrus occurrence and conception rates. In both studies, an increase in conception rates was observed during the waning phase, with a peak occurring immediately after the FM and persisting for several days (Kollerstrom and Power, 2000; Kollerstrom, 2004). Similarly, estrus activity was lower around the FQ, gradually increasing toward the FM. These results suggest a temporal alignment between the lunar cycle and reproductive rhythms in mares, potentially influenced by factors such as nocturnal light exposure or lunar-associated geomagnetic variations.

When comparing these findings with previous research on cattle, a distinct yet complementary pattern emerges. In bovines, conception rates are also greater during the waning phase, but the peak occurs in the second half of this phase, closer to the NM. This pattern was observed across different reproductive strategies, including artificial insemination (Aguirre et al., 2021), *in vitro* embryo production (Hernández-Fonseca et al., 2024) and *in vitro* embryo transfer (Perea et al., 2024a), where both pregnancy rates and embryo viability were significantly greater when fertilization or embryo transfer occurred in the last quarter of the lunar cycle. The differences between mares and cattle may stem from species-specific hormonal dynamics, reproductive cyclicity, and responses to environmental cues.

3.3 Sheep

3.3.1 Fertility, fecundity and lambing

Three studies have examined the effect of the lunar cycle on different reproductive aspects of sheep, all conducted in regions of the Northern Hemisphere.

In the first of these studies, data from 9,650 Merino ewes were analyzed over a 10-year period (Horak and Potucek, 1978). The lunar cycle, categorized into NM, FQ, FM, and LQ, significantly influenced the reproductive performance of the three sheep herds.

The distribution of estruses and conceptions was highest during the FM (28.8% and 28.6%, respectively), approximately 5 percentage points greater than in the other lunar phases. The number of inseminations per conception was lowest during the FM (1.74) and FQ (1.79) than during NM (1.85) and LQ (1.82). Additionally, the lambing rate per 100 ewes was greater in the FQ (123.5%) and FM (122.1%) than in the NM (119.1%) and LQ (92.4%). These findings suggest that estrus synchronization programs could benefit from timing mating around the FM and FQ.

In Egypt, 136 ewes from four different breeds were analyzed to assess the influence of the lunar cycle on various physiological indicators, including reproductive parameters (El-Darawany et al., 2014). Based on lambing timing within the 29.5-day lunar cycle, ewes were categorized as having lambed around the new moon (NM; days 0–7; n = 18), full moon (FM; days 11–18; n = 98), and old moon (OM; days 22–29; n = 20). The results showed that 72% of births occurred around the FM, compared to 13.2% during NM and 14.7% during OM. Litter weight and size varied among groups, with heavier litters in NM and larger litter sizes in OM. Although not statistically significant, lamb birth weight was 0.20 kg and 0.40 kg greater in FM than in NM and OM, respectively. However, mortality at birth was significantly higher in FM than in NM and OM, while litter size at weaning was greatest in OM. Although not relevant to the objective of this review, and therefore not detailed, the lunar cycle also influenced various physiological variables, including water and feed intake, as well as several parameters related to liver metabolism, and liver and kidney function (El-Darawany et al., 2014).

In Spain, an interesting study on Churra sheep (Palacios and Abecia, 2014) analyzed the relationship between the lunar cycle and reproductive variables in ewes inseminated by laparoscopy using fresh semen after spontaneous estrus (n = 383) or frozen semen following hormonal estrus synchronization (n = 2,341). The lunar cycle was categorized into four periods: NM, crescent moon (CM; waxing crescent to waxing gibbous), FM, and decreasing moon (DM; waning gibbous to waning crescent).

The lunar cycle significantly affected fertility (ewes lambing per inseminated ewes) and fecundity (lambs born per inseminated ewe), but not prolificacy (lambs born per lambing). Moreover, an interaction between estrus type and lunar phase was observed for all reproductive variables, indicating that the lunar effect on these parameters varied depending on the type of estrus. In general, all three reproductive variables were greater in ewes with induced estrus compared to those with spontaneous estrus. During the NM, fertility rates were lower after natural estrus detection (25%) and higher following estrus synchronization (60%). Regarding fecundity, the number of lambs per inseminated ewe after induced estrus was greater during NM (0.88 ± 0.05) and CM (0.85 ± 0.03) compared to FM (0.66 ± 0.05) and DM (0.63 ± 0.03). In contrast, for ewes with spontaneous estrus, fecundity was greater during CM (0.63 ± 0.03) and FM (0.61 ± 0.12) than during NM (0.33 ± 0.08) and DM (0.54 ± 0.04).

A study was conducted in Spain to analyze the relationship between the frequency of lamb births (n = 68,127) and the lunar cycle (Palacios and Abecia, 2011). Based on the assumption that the lunar cycle lasts 30 days (day 0 = FM, day 15 = NM), the cycle was divided into the following periods: FM (-3 to +3), CM (+4 to +11), NM (+12 to -11), and DM (-10 to -4). Although no significant differences were detected among lunar phases, a slightly greater percentage of births (3 to 5 percentage points) occurred during NM compared to the other phases.

The findings reviewed suggest that the lunar cycle influences several reproductive parameters in sheep, although the magnitude and nature of these effects may vary. In terms of estrus and conception rates, research on Merino ewes found increased estrus frequency and higher conception rates around the FM, with fewer inseminations required per conception during the FM and FQ, suggesting a possible lunar modulation of reproductive efficiency (Horak and Potucek, 1978).

Together, these findings support the hypothesis that lunar rhythms can influence key reproductive events in sheep. However, the heterogeneity in responses across breeds, reproductive strategies, and study conditions underscores the need for more controlled and systematic research to validate these effects and clarify the physiological pathways through which lunar signals interact with reproductive function in this species.

3.4 Goats

3.4.1 Puberty, birth and pregnancy rate

In goats, only three studies have reported the influence of the lunar cycle on reproductive activity. One of them, conducted in Egypt (El-Darawany et al., 2021), categorized 36 weaned kids based on their birth phase: NM (0–7 days), FM (11–18 days), and OM (22–29 days), following the methodology described by El-Darawany et al. (2014). The study tracked the animals from birth to puberty, assessing body measurements, estrus detection, cervical mucus characteristics, and blood parameters. Female kids born during FM had greater body weight at 20, 24, and 28 days of age compared to those born in NM and OM, with significant differences observed only between FM and OM. Age at puberty, determined by progesterone concentrations, was lower in females born during FM than in those born in NM and OM, with significance only between FM and OM. The elasticity and fern-like pattern of vaginal mucus were significantly higher in females born during FM than in those born in other lunar phases. Additionally, progesterone concentrations at 26 and 27 weeks were significantly higher in females born during FM compared to NM and OM (El-Darawany et al., 2021).

Records from three goat herds (n=624) consisting of Hair, Saanen × Hair, and Alpine × Hair breeds in Turkey were analyzed (Erduran, 2025a). Based on the lunar phase at the time of parturition, goats were categorized into eight phases: new moon, waxing crescent, first quarter, waxing gibbous, full moon, waning gibbous, last quarter, and waning crescent. A total of 44% of goats gave birth during the FM and waning gibbous phases, while the remaining 56% of births occurred across the other six phases. When the lunar cycle was grouped into dark nights (new moon, waxing crescent, and waning crescent), bright nights (full moon, waxing gibbous, and waning gibbous), first quarter, and last quarter, it was observed that goats that gave birth during bright nights had shorter gestation periods than those giving birth during dark nights and the first quarter, but the gestation length was similar to those that gave birth during the last quarter.

Erduran (2025b) evaluated the influence of lunar phase, among other factors, on reproductive performance in 217 Saanen goats under semi-intensive management in Konya, Turkey. Although several variables were assessed, the analysis of conception and parturition frequencies in relation to lunar phases yielded particularly relevant findings. For statistical purposes, the synodic lunar cycle (29.54 days) was categorized into four intervals: bright nights (waxing and waning gibbous, full moon), dark nights (waxing and waning crescent, new moon), first quarter to waxing gibbous, and third quarter to waning crescent. The raw data showed that 53.0% of parturitions occurred during dark nights and 22.0% during bright nights, with much lower frequencies recorded during the first (4.0%) and third quarter (21.0%) intervals. To better interpret these patterns, frequencies were standardized by phase duration. Parturition rates per day were highest during dark nights (8.37 births), the third quarter to waning crescent (7.3 births), followed by bright nights (6.1 births), and the first quarter to waxing gibbous (3.2 births). These results point to a genuine clustering of reproductive events during darker lunar phases, particularly around the waning moon, partially consistent with findings in other species such as cattle and buffaloes.

Although pregnancy rate, abortion rate, and offspring survival did not differ significantly among lunar phases, gestation length was significantly affected, being longest during dark nights and shortest during bright nights. Overall, this study provides further support for the hypothesis that lunar rhythms may influence the timing of key reproductive events in goats (Erduran, 2025a, 2025b).

3.4.2 Semen quality in bucks

In Egypt, 33 male goats were monitored to assess the influence of the lunar phase at birth, categorized as FM, NM, and OL, on growth rate, age at puberty, testosterone concentration, and semen characteristics (El-Tarabany et al., 2021). Bucks born during the FM phase grew faster, reached puberty approximately two weeks earlier, and produced ejaculates with greater volume, sperm concentration, motility, and viability than those born in NM or OL. Additionally, they showed higher testosterone concentrations between weeks 25 and 28, suggesting a sustained hormonal effect associated with the lunar phase at birth.

3.5 Buffaloes and camels

3.5.1 Postpartum intervals and the distribution of spontaneous parturition

For each species, only one study is available on the relationship between the lunar cycle and reproduction. In buffaloes, 3,510 reproductive records from a commercial farm located south of Lake Maracaibo, Venezuela, were analyzed (Aranguren-Méndez et al., 2023). The lunar cycle was split into 30 periods of 0.98 days each. The moon did not influence the calving to first estrus interval, the number of services per conception, or the first service conception rate. However, it significantly affected the calving to conception interval, which was longer around the NM (154.9 ± 4.5 days) than during the FM (141.9 ± 4.0 days) and most of the waning phase (138.0 ± 4.3 days). Additionally, as observed in cattle, calving frequency was significantly greater around the NM (17.5%) and FM (14.6%) than during the remaining 26 days of the lunar cycle (2.6% each).

A study on Canarian dromedary camels examined (n = 415) the influence of the lunar cycle on the spontaneous onset of labor (Iglesias Pastrana et al., 2023). While no statistically significant differences were found in the overall distribution of births across lunar phases (eight phases), the study identified a non-negligible effect of the NM on labor onset. Additionally, male calves were more likely to be born during brighter lunar nights, suggesting a potential adaptation linked to environmental cues. These findings indicate that the lunar cycle may play a role in modulating birth timing in camels, although further research is needed to clarify the underlying mechanisms.

3.6 Pigs

3.6.1 Reproductive performance in sows

The relationship between the lunar cycle and reproductive performance in sows was studied on a pig farm in Zulia State, Venezuela (n = 12,719) between 2017 and 2022 (Pichazaca and Zhirzhán, 2023). Based on the percentage of lunar illumination, the lunar cycle was divided into eight phases of approximately 3.7 days each: phase 1 (new moon to waxing crescent), phase 2 (waxing crescent to first quarter), phase 3 (first quarter to waxing gibbous), phase 4 (waxing gibbous to full moon), phase 5 (full moon to waning gibbous), phase 6 (waning gibbous to third quarter), phase 7 (third quarter to waning crescent), and phase 8 (waning crescent to new moon).

In nulliparous sows, the lunar phase at birth influenced the interval from birth to first conception, although it did not affect the number of services per conception. This interval was longer during the waxing than during the waning period of the lunar cycle (243.1 ± 0.42 vs. 240.6 ± 0.41 days, respectively). When considering the lunar phase at farrowing, an effect was observed on the interval from farrowing to conception, litter size and weight, and piglet mortality. Overall, sows had shorter conception intervals in phases 4 and 6 and longer ones in phases 7 and 8. Slightly more piglets were born during the waxing period than the waning period, but they were also slightly lighter. Piglet mortality varied throughout the lunar cycle, with significantly lower mortality rates in phases 1, 5, and 7 (Pichazaca and Zhirzhán, 2023).

3.6.2 Semen quality in boars

Two studies have examined the influence of the lunar cycle on the seminal characteristics of boars, conducted in temperate and tropical climate. A study conducted in the United States analyzed 4,149 ejaculates from 127 boars of various breeds between January

2014 and April 2017 (Chinchilla-Vargas et al., 2018). The study considered four lunar phases: FM (fully illuminated), NM (not visible), FQ (half illuminated, increasing), and LQ (half illuminated, decreasing). Each phase included the day of the phase plus the two days before and after. Additionally, the influence of the lunar cycle was assessed at the time of semen collection and 45 days prior, when spermatogenesis begins in boars.

At the onset of spermatogenesis, the lunar cycle affected the number of semen doses produced, which were greater during FQ, but had no effect on ejaculate volume or sperm concentration. However, on the day of collection, ejaculate volume was significantly lower during FM than in the other lunar phases. Similarly, more semen doses were produced during LQ than during FM. As in other cases, this study also demonstrated a clear lunar effect several weeks later (Chinchilla-Vargas et al., 2018).

On a pig farm in Zulia State, Venezuela, 3,315 semen samples were analyzed from 69 boars aged between 12 and 36 months (Pesántez, 2025). The lunar cycle was categorized into eight phases, as described by Pichazaca and Zhirzhán (2023). The lunar cycle on the day of semen collection significantly affected sperm concentration, total sperm count, and semen dose production, but had no impact on ejaculate volume or progressive individual motility. Sperm concentration remained relatively stable during the waxing phase (phases 1-4) but showed maximum and minimum values during the waning phase (phases 6 and 7, respectively). A similar pattern was observed for total sperm count and semen dose production.

In boars, the lunar cycle appears to affect semen quality, particularly sperm concentration and total sperm count (Pesántez, 2025), while other traits such as ejaculate volume and motility remain largely unaffected. Interestingly, lunar phase effects were observed both at the onset of spermatogenesis and on the day of semen collection (Chinchilla-Vargas et al., 2018), suggesting a delayed but measurable influence of lunar rhythms on testicular function. Although the underlying mechanisms remain unclear, these findings are consistent with studies in females and support the broader hypothesis that lunar cues may modulate reproductive physiology in swine.

3.7 Guinea pigs

3.7.1 Reproductive performance, follicle count, and gonadal steroids

In several Andean countries, such as Ecuador, Peru, Bolivia, and Colombia, domestic guinea pigs have been raised as a food source for centuries (Avilés et al., 2014). Their meat is highly valued for its taste and excellent quality (Sánchez-Macías et al., 2018), making it a staple in the Ecuadorian highlands. In this species, only two studies have assessed the influence of the lunar cycle on various reproductive aspects, both conducted in Azuay Province, Ecuador.

In a retrospective study, data from 7,352 female guinea pigs were analyzed for the period 2015–2018 (Perea M.F. et al., 2024). The lunar cycle was divided into eight periods, as described by Pichazaca and Zhirzhán (2023). The effect of the lunar cycle was studied at two time points: mating and parturition. The estimated mating date was calculated by subtracting 65 days (the average gestation length) from the parturition date. The lunar cycle at the time of mating influenced litter size and the number of pups weaned, with significantly greater averages in two of the four periods (2 and 3) of the crescent phase compared to the other lunar periods. Additionally, an effect on pup mortality was observed, with higher mortality rates in periods 3 and 5 and markedly lower mortality in period 4.

Regarding the phase of the lunar cycle at the time of birth, litter size was highest in period 3, followed by periods 4 and 2, while the lowest values were observed in the remaining periods, with the lowest peak occurring in period 6 of the waning phase. The number of weaned pups varied considerably, showing high peaks in periods 2, 4, and 7, while reaching a notably low point in period 6. Similarly, mortality was very high in periods 2 and 4, followed by period 7, and markedly lower in period 6. Individual and litter weights at weaning were also significantly influenced by the lunar phase, displaying multiple peaks above and below the population average (Perea M.F. et al., 2024).

Eighty nulliparous guinea pigs, aged between 3 and 3.5 months and with an average body weight of 1061 ± 90 g, were randomly assigned to four phases of the lunar cycle (n = 20 each; 5 animals per phase across 4 consecutive lunar cycles): NM, FQ, FM, and TQ (Perea et al., 2024c). The ovaries were weighed and processed histologically, and different follicular categories were counted. Additionally, progesterone and estradiol concentrations were quantified.

The lunar phase affected several ovarian parameters in guinea pigs. The number and percentage of large antral follicles were highest during NM compared to the other phases, whereas the number and percentage of primordial follicles were higher during FM and lowest during TQ (Figure 4). Hormone levels also varied, with progesterone and estradiol concentrations peaking in NM. In contrast, the number of corpora lutea and other follicle types remained unchanged across phases (Perea et al., 2024c).

The studies on guinea pigs reveal a medium-term effect of the lunar cycle on reproductive outcomes, as the lunar phase at mating, near the time of oocyte fertilization, affected events occurring well beyond the 65-day gestation period, extending into the postnatal phase (65–95 days), when the pups reached weaning (Perea M. F. et al., 2024). Specifically, litter size and the number of weaned pups were greater when mating occurred during the crescent phase, demonstrating a persistent influence of lunar rhythms on reproductive success.

In addition, the consistency between follicular development and ovarian steroid concentrations provides strong evidence of lunar modulation at the endocrine level (Perea et al., 2024c). The number of large antral follicles was highest during NM, which corresponded with the peak in estradiol concentrations, reinforcing the well-established role of antral follicles as primary producers of estradiol (Monniaux et al., 1997). This synchronization suggests that the lunar cycle may influence follicular recruitment and endocrine function, potentially shaping reproductive activity in this species.

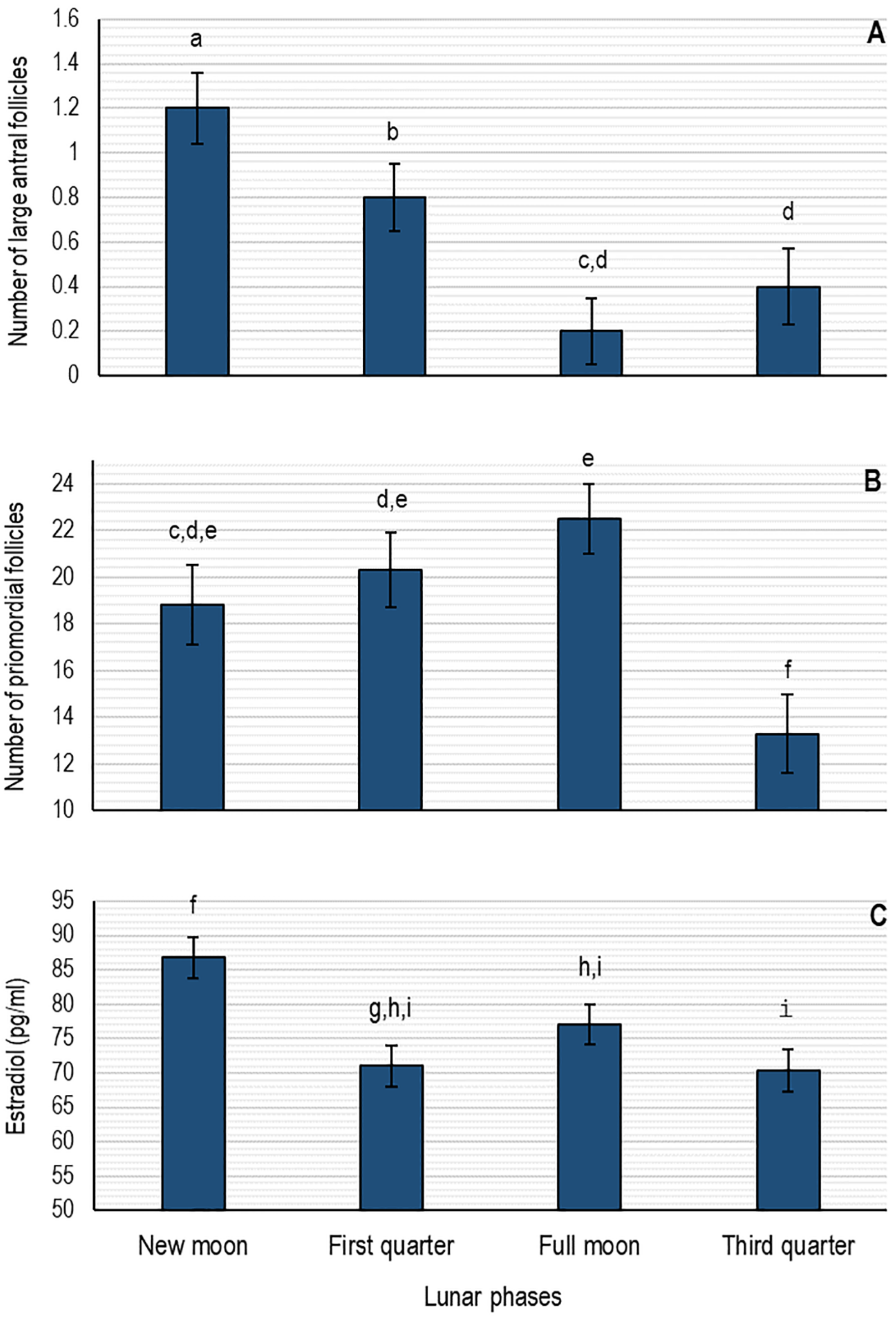

FIGURE 4
Influence of the lunar cycle on follicular count and estradiol concentration in nulliparous guinea pigs. **(A)** Effects of the lunar cycle on the number of large antral (P = 0.0005) and **(B)** primordial follicles (P = 0.0019), and **(C)** estradiol concentrations (P < 0.0001). The number and proportion of the remaining categories of follicle or corpora lutea were no affected by lunar cycle. Statistical differences among phases: **(A)**, $^{a\text{-}c}$P < 0.0001; $^{a\text{-}d,b\text{-}c}$P < 0.01; $^{a\text{-}b,\ b\text{-}d}$P < 0.087; **(B)**, $^{c\text{-}f}$P < 0.05; $^{d\text{-}f;\ e\text{-}f}$P < 0.01; **(C)**, $^{f\text{-}g,f\text{-}i}$P < 0.001; $^{f\text{-}h}$P > 0.05. Adapted from Perea et al. (2024c). *Influence of the lunar cycle on serum progesterone and estradiol concentrations, and follicular count in guinea pigs*. Animal Reproduction, 21(3). 37th Annual Meeting of the Brazilian Embryo Technology Society (SBTE). Atibaia, SP, Brazil. August 21-23, 2024.

3.8 Poultry

3.8.1 Egg morphology, laying rate and seminal traits

In domestic fowl, three studies have related the lunar cycle to reproductive activity, two in hens and one in roosters. On a commercial farm near Cuenca, Ecuador, 40 consumer eggs were collected at four points in the lunar cycle (NM, FQ, FM, LQ) over four consecutive lunar cycles (n = 640) (Sinchi and Sisalima, 2025). The weight, length, and width of each egg, as well as measurements of the yolk, albumen, and shell (including weight and thickness), were recorded, along with various derived variables. A significant effect of the lunar cycle was observed on egg weight, length, and width, as well as shell weight, thickness, and shell-to-egg ratio, though egg shape remained unchanged across lunar phases. Similarly, the lunar phase significantly influenced yolk weight, diameter, and height, as well as albumen weight and diameter, but not albumen height. Additionally, the yolk-to-egg, albumen-to-egg, and yolk-to-albumen ratios were also affected by the lunar cycle. However, no effect of the lunar cycle on egg quality was detected. Overall, the morphometric variables of the eggs were greater in LQ and NM than in FQ and FM (Sinchi and Sisalima, 2025).

On a commercial farm producing fertile eggs (Cobb 500 breed) in Azuay Province, Ecuador, forty-eight laying cycles were studied over a six-year period (2016–2021). A total of 17,558 daily production records were analyzed between weeks 26 and 56 of age, corresponding to a total population of approximately 430,000 hens (Fárez and Quezada, 2024).

This study evaluated the influence of the lunar cycle at two key points: (1) at the estimated time of fertilization of the eggs that gave rise to the hens studied, which was calculated as the hatching date minus 25 days (1 day from fertilization to laying + 3 days of storage + 21 days of incubation); and (2) on the day of egg laying, during the production stage starting at week 26 of age. Based on the percentage of lunar illumination, the lunar cycle was divided into eight periods, following the classification described by Pichazaca and Zhirzhán (2023).

The effect of the lunar cycle was more pronounced at the time of egg fertilization than on the day of laying. Variables such as egg production, laying percentage, the quantity and percentage of hatchable eggs, and mortality were significantly affected when considering the lunar phase at fertilization, whereas the effects on the day of laying were more attenuated or not significant (Fárez and Quezada, 2024).

A study evaluated the effect of meteorological conditions and the lunar cycle on the post-thawing quality of avian sperm (Díaz Ruiz et al., 2024). A total of 108 semen samples were analyzed from 16 Urterana roosters aged 1 to 3 years. The lunar cycle was divided into eight phases based on lunar illumination percentages. The study found that post-thaw sperm quality was significantly influenced by the lunar phase at the time of collection, with all samples obtained during the new moon being classified into the poorest quality group. Additional, though less consistent, effects were also observed during the waxing gibbous and waning crescent phases.

3.9 The lunar cycle and offspring sex ratio

There has been much speculation about whether specific phases of the lunar cycle at the time of fertilization influence the sex of offspring. Numerous studies on domestic animals, including both monotocous and polytocous species, have explored this topic with mixed results. While some findings support the phenomenon, others do not. However, most large-scale analyses have concluded that the lunar phase has no significant effect on offspring sex ratio.

The study by Abecia et al. (2016) provides a comprehensive analysis of the relationship between the lunar cycle and the offspring sex ratio in four livestock species. The dataset included 79,065 births that produced 100,008 offspring of farm animals raised in Spain: sheep (n = 51,407 births, 66,830 lambs), cows (n = 24,268 births, 25,546 calves), goats (3,150 births, 5,671 kids), and pigs (240 births, 1,916 piglets). The lunar cycle was categorized into four phases: NM, CM (waxing crescent to waxing gibbous), FM, and WM (waning gibbous to waning crescent). This large-scale analysis aimed to determine whether the lunar phase at conception influenced the sex ratio of offspring in these species.

No effect of the lunar cycle on the sex ratio in sheep was observed. However, the season of conception had a significant influence, with a greater proportion of males born in spring and winter and a lower proportion in summer and autumn. In cattle, neither the lunar phase nor the season individually affected the sex ratio; however, a highly significant interaction between these factors was found, suggesting a combined effect. In goats, no influence of the lunar cycle or the season on the sex ratio was detected. In pigs, neither the lunar phase nor the season had a significant effect on the sex ratio; however, the proportion of males among piglets conceived during the waxing phase and in summer was significantly greater than 1:1. Overall, the lunar cycle had no consistent impact on the sex ratio at birth in the species examined, although it may interact with other factors, such as the season, in some cases (Abecia et al., 2016).

In a retrospective study (2003-2011) conducted in Argentina on Thoroughbred and Arabian horses, 65,535 births were analyzed (Aguilar et al., 2014). The lunar cycle was categorized in three different ways: 1) the four classical phases (waxing crescent, waxing gibbous, waning gibbous, and waning crescent), each lasting approximately 7.4 days; 2) a division of the complete cycle into 29 one-day periods plus a final period of 0.6 days, sequentially numbered to indicate the number of days relative to the NM; and (3) classification based on Perigee and Apogee positions of the Moon.

The overall sex ratio at birth was 33,396 fillies (50.96%) and 32,139 colts (49.04%). No significant association was found between the lunar phase at the time of copulation and the sex of the foal at birth. Although minor fluctuations were observed on certain days, these differences were not statistically significant. When the data were grouped into the four lunar phases, the sex ratio remained close to 50:50, with no significant variation (Aguilar et al., 2014).

A study conducted in the metropolitan region of Belo Horizonte, Minas Gerais, Brazil, analyzed reproductive data from two stud farms to assess the influence of the lunar cycle on ovulation, fetal sex ratio at 60–70 days of gestation, and parturition timing (Marinho et al., 2015). A total of 233 estrous cycles from 111 mares, 348 pregnancies, and 356 births were evaluated. The lunar cycle was categorized into four phases: new moon, waxing moon, full moon, and waning moon.

The study found that the lunar phase did not affect ovulation rates, fetal sex ratio at 60–70 days, or parturition incidence. However, the male-to-female sex ratio at birth was significantly influenced by the lunar phase, with a greater proportion of male foals born during the waning moon compared to the new and waxing moons (Marinho et al., 2015).

In tropical cattle, 121,276 births were analyzed from 36 farms in the western region of the Lake Maracaibo basin, Venezuela (Perea et al., 2024b). The lunar cycle was divided into 30 periods, each lasting 0.984 days, based on the percentage of lunar illumination. Overall, the proportion of male calves (51.3%) exceeded that of females (48.7%). However, data analysis revealed no significant influence of the lunar cycle on the sex ratio, with male percentages ranging from 50.0% to 52.7% and female percentages from 47.3% to 50.0%.

In guinea pigs, an analysis of 7,352 births on a commercial farm in Ecuador revealed a sex ratio of 49.9% males and 50.1% females (Perea M.F. et al., 2024). The lunar cycle, categorized into eight periods, had no significant influence on the sex ratio at birth, with female percentages ranging between 48.1% and 53.2% across the lunar periods analyzed.

In canines, a study conducted in Italy analyzed the sex distribution of 973 puppies (48% females, 52% males) born to 150 Labrador Retriever bitches between 2015 and 2020 (Alberghina et al., 2021). The lunar cycle was categorized into four phases: new moon, waxing moon, full moon, and waning moon, each lasting approximately 7.4 days.

The overall sex ratio was 1.09 (509 males and 468 females). While the season had no effect on the sex distribution, the lunar phase at conception significantly influenced the proportion of male offspring ($p < 0.05$). Specifically, the proportion of males was significantly lower when conception occurred during the NM compared to the FM phase (Alberghina et al., 2021).

In the same species, a study conducted in two breeding facilities in northern Italy analyzed 78 matings and parturitions from Dobermann, Golden Retriever, and Samoyed breeds (Fusi et al., 2025). The lunar cycle was categorized into four phases: new moon, waxing moon, full moon, and waning moon. The study found that mating occurred most frequently during the waning moon and least frequently during the waxing moon, while parturitions were more common during the NM and less frequent during the waxing moon. Additionally, mating during the NM and waxing moon was associated with a higher male-to-female ratio, whereas mating during the FM and waning moon resulted in a lower proportion of males. Interestingly, all conceptions during the FM led to births during the FM, suggesting a possible synchronization effect between conception and parturition (Fusi et al., 2025).

4 Biological mechanisms explaining lunar-driven variations in reproductive activity

To date, no studies have specifically explained the biological mechanisms underlying the influence of the moon on reproductive activity in mammals in general, and in farm animals in particular. However, the integration of evidence from various biological and geophysical findings could provide a plausible explanation for this phenomenon.

In an insightful review, Bevington (2015) explores the biological effects of the lunar cycle and proposes mechanisms through which the moon may influence biological activity. Based on scientific evidence, the author argues that traditional explanations focusing on lunar gravity and light are insufficient to account for the observed biological effects. Instead, the study highlights the role of electromagnetic fields, particularly disturbances in the Earth's magnetosphere, which occur continuously throughout the lunar cycle, with varying intensity depending on the moon's position. The moon's interaction with the Earth's magnetic field, particularly in relation to the Sun, causes electromagnetic fluctuations (Stolov, 1965; Bell and Defouw, 1966) that may influence physiological processes in organisms sensitive to these stimuli, such as calcium ion flux (Pall, 2013), cryptochrome activity (Nießner and Winklhofer, 2017), and magnetoreception via magnetite-based mechanisms (Shaw et al., 2015) (reviewed in Henshaw and Philips, 2025).

This raises the question of how animals transduce electromagnetic stimuli generated by the moon's orbit around the earth, detected by one or more magnetosensitive mechanisms, into physiological signals capable of influencing peripheral tissues. According to numerous experimental findings, the pineal gland, through the secretion of melatonin, seems to be the most plausible intermediary.

Multiple studies have shown that the pineal gland responds to variations in the magnetic field by modifying the melatonin secretion pattern. In rodents and birds, pinealocytes showed electrophysiological responses to weak magnetic fields, comparable in intensity to the Earth's field (Seem, 1983; Olcese et al., 1988). This sensitivity seems to be partially mediated by retinal photoreceptors, which may transmit geomagnetic information to the pineal via neural pathways (Reuss et al., 1983; Olcese, 1990).

At the molecular level, cryptochromes, present in magnetosensitive tissues such as the retina and possibly the pineal gland, mediate responses to weak electromagnetic fields via radical pair mechanisms (Nießner and Winklhofer, 2017; Henshaw and Philips, 2025). In addition, magnetic field exposure has been associated with alterations in calcium ion flux in pinealocytes (Pall, 2013), a key component in signal transduction and neuroendocrine regulation.

In fish, melatonin has been proposed as a key transducer of lunar-related reproductive rhythms. In lunar-synchronized spawners such as the goldlined spinefoot (*Siganus guttatus*), melatonin concentrations increase near the NM and decrease around the FM, in line with fluctuations in melatonin receptor expression (Takemura et al., 2004; Ikegami et al., 2014). These changes are believed to coordinate the activation of the hypothalamic–pituitary–gonadal axis, leading to synchronize spawning activity. Evidence from studies in rodents (Martinez Soriano et al., 2002a, 2002b; Gerasimov et al., 2014) and humans (Cajochen et al., 2013) indicates that melatonin secretion may fluctuate according to the lunar cycle.

In rats and mice, the pineal gland exhibited both structural and functional changes related to its secretory activity, with a greater melatonin-producing capacity observed during the FM phase compared to the NM phase (Martinez Soriano et al., 2002a, 2002b; Gerasimov et al., 2014). Interestingly, lunar phase-dependent structural changes have also been documented in peripheral tissues such as the submandibular salivary glands, which express melatonin receptors (Isola et al., 2022) and respond morphologically in synchrony with changes in the pineal gland (Gerasimov et al., 2014), suggesting that melatonin may mediate systemic responses to stimuli related to the lunar cycle.

Melatonin receptors have been identified in various reproductive tissues across mammalian species (reviewed by Gao et al., 2022). These include central regulatory structures such as the hypothalamus and pituitary gland (reviewed by Ng et al., 2017; Charif and Dorfman, 2025), as well as peripheral tissues like the ovaries of cows (He et al., 2016; Wang et al., 2018) and the myometrium of women (Schlabritz-Loutsevitch et al., 2003), rats (Steffens et al., 2003), and cows (Dirandeh et al., 2022). Melatonin has also been implicated in modulating myometrial contractility and the timing of parturition, acting synergistically with oxytocin (Sharkey et al., 2009; Takayama et al., 2003). In males, melatonin receptors have been identified in the testes and other reproductive tissues (González-Arto et al., 2017; Kozioł et al., 2020), where melatonin has been associated with enhanced testosterone production and stimulation of spermatogenesis (Yang et al., 2021). Collectively, this evidence suggests that melatonin, modulated by lunar-related electromagnetic fluctuations, may act as a central mediator in the physiological mechanisms underlying reproductive variation in farm animals (Figure 5).

5 Integrative discussion

Despite species-specific differences in reproductive physiology and management, the collective evidence reviewed supports the notion that the lunar cycle exerts varying degrees of influence on reproductive activity in farm animals. Although the type and magnitude of this influence vary, several recurring patterns emerge: increased conception rates at certain periods of the lunar cycle (Aguirre et al., 2021; Pinedo et al., 2025), greater birth rates around the NM and FM phases (Yonezawa et al., 2016; Perea et al., 2024b), phase-dependent changes in gamete competence and quality (Hernández-Fonseca et al., 2023, 2024; Pesántez, 2025), and alterations in the timing of ovulation or parturition (Fusi et al., 2025).

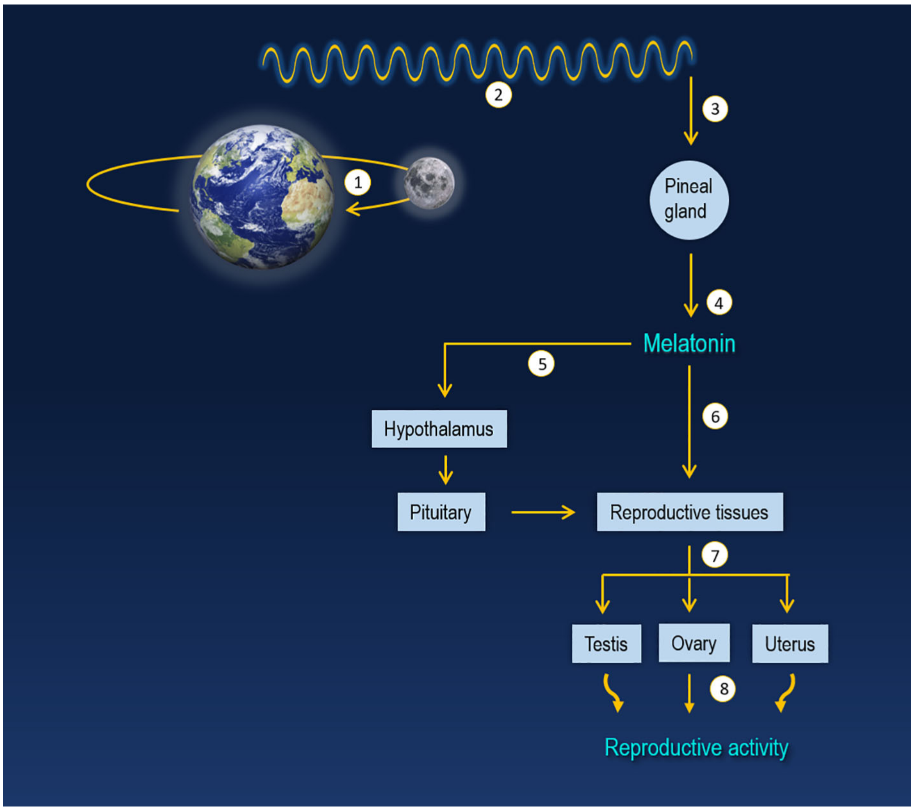

FIGURE 5
Biological mechanisms describing lunar-driven variations in reproductive activity. The Moon's orbital movement around the Earth (1) causes periodic variations in the planet's geomagnetic field (2) (Bell and Defouw, 1966). The pineal gland detects these electromagnetic changes (3) (Olcese, 1990) and responds by altering its melatonin secretion pattern (4) (Seem, 1983). This hormone binds to receptors in hypothalamic neurons and the pituitary gland (5) (Charif and Dorfman, 2025), indirectly modulating reproductive function. Additionally, melatonin acts directly on reproductive tissues (6) (Gao et al., 2022) through its receptors in the testes (Yang et al., 2021), ovaries (He et al., 2016), and uterus (7) (Dirandeh et al., 2022), ultimately influencing reproductive activity (8) of farm animals (Gao et al., 2022).

Notably, the influence of the lunar cycle has also been documented in seasonal breeders such as sheep, goats, buffaloes, and mares, species whose reproductive activity is primarily regulated by photoperiod and mediated by melatonin (Chemineau et al., 2008; Goodman, 2015). In these animals, the detection of lunar effects during the breeding season, when the hypothalamic–pituitary–gonadal axis is already activated, suggests that moon-related cues may exert additional modulation on reproductive processes. Such findings underscore the biological plausibility of lunar influences, even in species whose reproductive cycles are tightly entrained to seasonal light-dark patterns (Palacios and Abecia, 2014; El-Darawany et al., 2021; Kollerstrom, 2004). Whether these lunar effects extend beyond the breeding season remains unexplored, highlighting an important gap for future research.

These patterns have been observed not only in spontaneous reproductive events, but also under controlled conditions such as artificial insemination (Aguirre et al., 2021), estrous synchronization (Palacios and Abecia, 2014), *in vitro* embryo production (Hernández-Fonseca et al., 2024), and embryo transfer (Perea et al., 2024a), suggesting that moon-related effects may persist even when assisted reproductive technologies are used. At the same time, inconsistencies reported both across and within species highlight the probable involvement of multiple interacting factors. The amount of data analyzed and the criteria used to categorize lunar phases can influence the outcomes. While some traits, such as sex ratio, appear unaffected or inconsistently influenced by lunar phases, the recurrence of other patterns across species and reproductive contexts provides compelling evidence of an underlying biological sensitivity to lunar rhythms.

Interestingly, some studies have shown that the lunar influence on reproductive activity may vary depending on geographic location, raising the possibility that latitude, geomagnetic factors, or lunar orbital parameters could modulate these effects. For instance, the conception rate at first service in dairy cattle was found to be higher during the waxing phase than during the waning phase in southern latitudes of South America (Perea et al., 2025a, 2025b), whereas the opposite pattern was reported in studies conducted further north, including in Brazil, Venezuela, and the United States (Aguirre et al., 2021; Perea et al., 2024a; Pinedo et al., 2025).

A potential explanation may lie in the modulation of the Earth's geomagnetic field by the Moon. Several early studies demonstrated that lunar modulation of geomagnetic activity is greatest when the Moon is near the ecliptic plane, and that the geomagnetic response varies with the Moon's celestial latitude, especially around full moon phases (Bell and Defouw, 1966; Markson, 1971). This suggests that lunar effects on geomagnetic parameters—and possibly on biological systems—may vary with geographic latitude and season, depending on the Moon's orbital trajectory relative to the Earth's magnetotail.

In line with this evidence, Kollerstrom (2004) found that fertility in Thoroughbred mares was significantly influenced by the lunar nodal cycle. Specifically, mares inseminated when the Moon was near one of its two lunar nodes (where it crosses the ecliptic) had higher conception rates than those inseminated when the Moon was far from a node. This supports the hypothesis that lunar modulating effects on fertility may be more likely or pronounced when the Moon lies near the ecliptic plane—its optimal position to interact with Earth's geomagnetic field.

Furthermore, because the Moon's distance from Earth and its orbital inclination fluctuate over time, its capacity to interact with geomagnetic forces might also vary both geographically and temporally. Schneider (1967) proposed that lunar effects on the magnetosphere might intensify when the Moon is close to the ecliptic, altering the magnetotail structure and potentially influencing surface-level geomagnetic activity (Bell and Defouw, 1966; Schneider, 1967). These insights open the possibility that geomagnetic modulation by the Moon could affect biological systems sensitive to magnetic or electromagnetic cues, including reproduction. However, whether these variations have a measurable impact on reproductive function across latitudes or seasons remains unknown and warrants multidisciplinary research.

Another interesting aspect that emerges from these studies indicates a medium-term effect of the lunar cycle, which in some cases has been associated with changes in the reproductive performance of farm animals. For example, goats, pigs and guinea pigs born during certain lunar phases reached puberty earlier (El-Darawany et al., 2021; El-Tarabany et al., 2021) or were weaned at a higher weight (Pichazaca and Zhirzhán, 2023; Perea M.F. et al., 2024) than in other phases of the lunar cycle. In poultry, reproductive outcomes were more strongly associated with the lunar phase at the time of fertilization than at the time of laying (Fárez and Quezada, 2024), indicating a possible programming effect in the early stages of life. These findings suggest that, similar to other stressors such as heat, malnutrition, and disease (reviewed by Sinclair et al., 2016), lunar influences may contribute to epigenetic reprogramming, ultimately affecting gene expression and biological function in these species.

Environmental conditions, photoperiod, genetic background, and species-specific sensitivity to electromagnetic or gravitational cues may modulate biological response. Nonetheless, lunar phase-related variations in reproductive activity documented in mammals (Chinchilla-Vargas et al., 2018; Palacios and Abecia, 2014), birds (Norevik et al., 2019; Fárez M and Quezada Ll, 2024), and fish (Takemura et al., 2004; Perea et al., 2022) suggest the existence of a shared biological interface capable of transducing lunar signals. The pineal gland, acting through melatonin, emerges as a plausible and unifying mechanism (Seem, 1983; Olcese et al., 1988; Martinez Soriano et al., 2002a; Gerasimov et al., 2014), warranting further investigation. A multidisciplinary approach, integrating chronobiology, reproductive endocrinology, and geophysical monitoring, is necessary to clarify how these components interact to shape lunar-driven reproductive processes, especially given the limited understanding of underlying mechanisms and the need for species- and context-specific studies.

6 Conclusions

The evidence compiled in this review indicates that the lunar cycle may influence various aspects of reproductive activity in farm animals, including conception rates, birth timing, gamete and embryo quality, and even productive traits. While the magnitude and direction of these effects are not always consistent across species or studies, the recurrence of phase-dependent patterns, especially around the new moon and full moon, suggests that lunar rhythms remain biologically relevant, even under modern animal production systems.

The diversity of findings across livestock species points to the existence of a shared underlying mechanism, with melatonin emerging as a likely key mediator. The pineal gland, known to be sensitive to electromagnetic fluctuations associated with lunar phases, may act as the interface between geophysical cues and endocrine signals that regulate reproductive processes.

Recognizing the Moon as a potential modulator of reproductive biology opens new avenues for research and may help explain previously overlooked sources of variation in reproductive outcomes. Future studies should seek to elucidate the physiological pathways involved, determine the adaptive significance of lunar synchronization in farm animals, and explore the practical implications for reproductive management and livestock productivity.

Author contributions

FP: Conceptualization, Validation, Writing – review & editing, Methodology, Formal analysis, Writing – original draft. MP: Supervision, Methodology, Investigation, Writing – original draft, Formal analysis. MP-B: Formal analysis, Writing – original draft, Data curation, Validation, Conceptualization. MM: Validation, Writing – original draft, Supervision, Investigation, Visualization, Formal analysis.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The author(s) declare that Generative AI was used in the creation of this manuscript. The authors wrote the manuscript, and ChatGPT (OpenAI, GPT-4, accessed via chat.openai.com) was used to improve the clarity and fluency of the English language. All outputs were reviewed and verified by the authors to ensure accuracy and compliance with publication standards.

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