Mini Review
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Effects of electromagnetic fields on performance in cattle

Abstract

Electromagnetic fields in cattle operations are often unnoticed, yet they represent a continuous environmental factor to which animals are exposed throughout the day. Control panels, motors, milking systems, fans, and waterers generate low-frequency magnetic fields. Although these levels are generally low, animals spend long periods near such equipment, and some studies have reported minor changes in indicators such as behavior, physiology, reproduction, and milk production. These indicators are fundamental measures that directly reflect animal welfare and productive performance. Behavior responds quickly to changes in the environment; physiological measures show the biological effects of stress; reproduction is sensitive to hormonal balance; and milk yield and milk composition can be influenced by small variations in environmental conditions.

Research on behavior has occasionally reported mild restlessness, brief avoidance responses, or slight changes in body orientation. In physiological indicators, small fluctuations in hormone levels and certain biological parameters have been observed. These changes are generally short-lived and not severe enough to affect animal health. Findings related to reproduction show a similar pattern, with no clear evidence that low-frequency magnetic fields impair fertility. Studies on milk yield and milk composition have also noted minor variations, although results remain inconsistent.

Overall, current research shows that electromagnetic field levels encountered in cattle operations are low and do not pose a significant concern for animal health or production. However, further studies under different management conditions are needed to better understand the effects of long-term exposure.

Keywords: electromagnetic field, behavior, physiology, reproduction, milk yield, milk composition

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Introduction

Electromagnetic waves (EM waves) are forms of energy in which electric and magnetic fields propagate synchronously, oriented perpendicular to each other and perpendicular to the direction of wave travel. These waves are generated by the accelerated movement of charged particles and propagate at the speed of light in a vacuum. In modern livestock farms, automatic feeding systems, sensors, milking robots, GPS-based monitoring systems, and wireless communication devices continuously generate such electromagnetic.[1,2] It has also been reported that exposure levels may increase in large-scale farms located near urban power lines, and that electromagnetic waves tend to reflect and accumulate within steel-framed barn structures.[3,4] Several studies suggest that these fields may cause restlessness, reduced milk yield, or alterations in orientation behavior in cattle.[5,6] In addition, long-term exposure may influence hormone secretion, immune responses, and reproductive functions.[4,7] Understanding the structure of the electromagnetic spectrum is essential for evaluating the low-frequency magnetic fields encountered in livestock production systems. The spectrum spans a broad range, and the main types of electromagnetic waves are summarized in Table 1.

This classification provides a fundamental framework for understanding the physical characteristics of low-frequency magnetic fields present in cattle farms. Electromagnetic measurements conducted in agricultural environments have shown that power lines, transmission systems, and electrical equipment within barns can generate notable magnetic field intensities.[3,8] Magnetic field intensities of 0.4–1.5 μT near power lines and 0.8 μT around automatic feeding systems, along with electric field strengths of 2.3 V/m, have been reported.[9] Within barns, magnetic field levels generally range between 0.2 and 0.6 μT.[5,7] Although these values appear low, continuous exposure becomes important because animals spend most of the day in these environments.

Table 1 Electromagnetic wave spectrum

Type	Wavelength	Application area
Radio Waves	> 1 mm	Communication, television, radio
Microwaves	1 mm – 1 cm	Radar, microwave ovens, Wi-Fi
Infrared (IR)	700 nm – 1 mm	Heating, night-vision equipment
Visible Light	400 – 700 nm	Visual perception, optical systems
Ultraviolet (UV)	10 – 400 nm	Sterilization, sunlight
X-rays	0.01 – 10 nm	Medical imaging
Gamma Rays	<0.01 nm	Nuclear energy, cancer therapy

Research on the biological effects of electromagnetic fields indicates that exposure may lead to cellular alterations, thermal effects, and long-term risks such as DNA damage or genetic mutations.[1] Some studies also show that artificial magnetic fields may induce stress, restlessness, behavioral abnormalities, sleep disturbances, and reduced productivity in livestock. Observations in pastures near high-voltage transmission lines indicate that cattle lose their natural magnetic alignment relative to Earth's geomagnetic field, and that alignment normalizes as distance increases.[5,6] These findings suggest that electromagnetic fields may exert indirect effects on cattle behavior and production parameters.

Electromagnetic fields (EMF) are an environmental factor present unnoticed in cattle operations, to which animals are exposed daily.[1]

Milking motors, electrical panels, fans, drinkers, and many similar devices generate low-frequency fields.[10] These fields are generally low in intensity; however, because animals spend most of their time in these environments, EMF has become a subject increasingly addressed in research. Recent studies have reported that low-frequency fields may occasionally be associated with behavior, hormone regulation, physiology, and milk production in cattle.[4,7] Some studies have noted mild changes in hormones such as melatonin, prolactin, or progesterone, although these changes are mostly temporary and do not significantly impair the animal's health status.[11] Studies on milk yield have generally shown no significant change, although minor variations in milk components have been reported.[1,10] From a behavioral perspective, short-term restlessness or slight differences in orientation have also been reported.[5,6]

The aim of this review is to evaluate, in a clear and structured manner, the relationship between electromagnetic field exposure in cattle farms and changes in behavior, physiology, reproduction, milk yield, and milk composition based on the current literature.

Materials and methods

In this review, literature published between 1986 and 2025 on the effects of low-frequency electromagnetic fields (EMF) in dairy cattle operations on animal health, welfare, and production performance was systematically examined. Both English and Turkish studies, including research articles, reviews, and scientific reports, were considered. The literature search was conducted using PubMed, Web of Science, Scopus, and Google Scholar databases.

The search strategy included keywords such as "cattle," "dairy cows," "electromagnetic fields," "low-frequency magnetic fields," "animal welfare," "milk production," and "reproduction." Studies were selected if they provided data on EMF exposure and evaluated behavioral, physiological, reproductive, or milk production parameters. Abstracts and titles were initially screened, and full-text articles meeting the inclusion criteria were reviewed.

Data from the selected studies were systematically extracted and analyzed, including EMF sources, exposure duration, measurement units, animal species and age groups, observed parameters, and key findings. Similarities, differences, and current knowledge gaps among the studies were compared and discussed.

Magnetic field sources and exposure levels in cattle farms

The primary sources of electromagnetic fields in cattle operations are electrical equipment and the farm's power infrastructure. Although these fields are low in intensity, the exposure is continuous, which makes them an important factor considered in research.[10,11] The highest magnetic field intensities are typically observed near electrical panels, motors, milking systems, vacuum pumps, automatic drinkers, fans, and lighting units. Microtesla values increase in close proximity to these devices and decrease rapidly with distance. Values ranging between 1–10 μT have been reported around panels and motors.[3,9] Short-term increases may also occur during milking due to the operating cycles of the equipment.[12]

Earth's natural magnetic field ranges between 25–65 μT.[1] The levels inside barns are significantly lower than this. Some studies report that even values between 0.5–5 μT may cause slight changes in certain behavioral parameters and milk composition indicators.[4,7] In farms located near high-voltage transmission lines, values exceeding 10 μT have been documented.[8,13]

Current findings indicate that exposure is "low but continuous," and that both field intensity and duration of exposure should be considered together when evaluating the effects of electromagnetic fields.[2]

Effects of magnetic fields on cattle behavior

Behavior is considered one of the most fundamental and reliable indicators of animal welfare. This is because an animal's physiological condition, responses to environmental factors, and emotional experiences can often be observed through its behavior. The ability to express species-specific natural behaviors (such as rumination, dust-bathing–like ground interactions, or play behavior) indicates that the animal's environmental and psychological needs are being met, and therefore reflects a high level of welfare. In contrast, the presence of stereotypic or abnormal behaviors (such as repetitive movements, excessive licking, or aggression) signals stress, discomfort, or environmental deprivation, all of which negatively impact welfare. Behavioral indicators such as social interactions, play behavior, and avoidance responses also provide valuable information for evaluating both individual and group-level welfare. Today, behavioral assessments can be conducted not only through direct observation but also through sensor-based monitoring systems and video-analysis technologies, making evaluations more objective. Therefore, when used together with physiological parameters, behavioral indicators allow for a holistic assessment of animal welfare and serve as a critical monitoring tool in sustainable livestock production systems.

Behavior is one of the indicators that respond rapidly to environmental changes. In the case of electromagnetic field exposure, some studies have described mild restlessness, short-term avoidance, and slight alterations in orientation.[7,13] These responses were more pronounced particularly in areas near electrical panels and motors, where field intensities of around 1–5 μT have been measured.[14] During milking, fluctuations in magnetic field intensity related to the operating cycles of equipment have been reported to cause short-term restlessness in some cows.[12] Studies on orientation behavior have also shown that animals' natural alignment patterns can be disrupted in areas surrounding high-voltage power lines.[5,6]

When all findings are evaluated together, behavioral changes appear to be small, inconsistent, and indicate that the overall impact of electromagnetic fields on cattle behavior is limited.

Physiological effects of magnetic fields

Stress, in the context of animal physiology, can be defined as the biological and behavioral adaptive response of the organism to environmental, physical, or psychological pressures. These pressures may arise from factors such as extreme heat or cold, inadequate nutrition, high stocking density, transportation, disease, social conflicts, or sudden environmental changes. Stress disrupts the animal's homeostasis and activates physiological mechanisms that support survival and adaptation. A key characteristic of stress is the distinction between its short-term (acute) and long-term (chronic) effects. Acute stress typically triggers adaptive responses that mobilize energy and enable the organism to cope with immediate challenges. However, chronic stress continuously affects hormone levels and metabolism, weakens the immune system, reduces reproductive and growth performance, leads to behavioral disturbances, and negatively impacts overall welfare. Studies examining the physiological effects of electromagnetic fields (EMF) have reported varying results. Some research indicates slight fluctuations in hormone concentrations, with small changes noted particularly in hormones such as melatonin, prolactin, and progesterone.[4,11] Although mild increases in certain

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stress indicators have been observed in some individuals, these findings cannot be generalized to entire herds.[7] Most studies report no significant alterations in hematological or biochemical parameters, while a few describe minor variations.[13]

Overall, the physiological effects of EMF appear to be limited, minimal, and often temporary.

Effects of magnetic fields on reproduction

Although numerous studies have investigated the effects of electromagnetic radiation (EMR) on reproductive health in humans, the number of studies conducted on animals remains quite limited. Several studies indicate that EMR may have adverse effects particularly on the female reproductive system. Frank et al.[15] reported that EMR exposure is associated with miscarriages and congenital anomalies. In a study conducted in the United States by Li et al.,[16] it was stated that daily average EMR exposure of 16 mG or higher increases the risk of miscarriage, with this risk being more pronounced in pregnancies less than 10 weeks (RR: 2.2). Similarly, London et al.[17] demonstrated that the rate of difficult labor increases in pregnant women who are exposed to above-average magnetic fields for extended periods. However, the findings regarding congenital anomalies are inconsistent; Blaasaas et al.[18] reported that exposure above 0.1 μT is not associated with congenital anomalies. The use of CRT-based resistant mattresses and video display terminals has also been found not to be associated with low birth weight.[19,20] In contrast, Blaasaas et al.[21] suggested that there may be an association between EMR exposure and congenital esophageal anomalies. It has also been reported that RF radiation may increase the risk of miscarriage and cause ossification defects in cases of prenatal exposure.[22] Additionally, Xu et al.[23] demonstrated that reproductive and endocrine functions may be impaired in female workers exposed to high-frequency EMR for more than one year.Most studies indicate that electromagnetic fields do not cause any significant negative effects on reproductive performance. No notable changes have been reported in estrous cycle patterns, progesterone levels, expression of estrus behaviors, or conception rates.24,25 Although some studies have observed minor hormonal fluctuations, these changes were reported not to affect fertility outcomes.[11] Research conducted in farms located near high-voltage transmission lines has reported certain differences; however, these findings are not generalizable.[8]

Overall, the impact of electromagnetic fields on reproduction appears to be limited.

Effects of magnetic fields on milk yield and composition

Most studies investigating milk yield have reported no significant changes associated with electromagnetic field exposure.[11] Some research has mentioned slight decreases; however, these findings are not consistent across studies.[13] Temporary increases in electromagnetic field intensity during milking have been noted to cause short-term restlessness in some cows.[12] Although farms located near high-voltage transmission lines have occasionally reported different outcomes, the overall trend suggests that electromagnetic fields do not have a strong effect on milk yield.

Some studies have reported small decreases in milk fat and slight variations in lactose levels.[4,7] Most of these changes are minor and not substantial enough to affect overall production.[11] Although slight increases in somatic cell count have been observed in certain cases, similar findings have not been consistently replicated across studies.[13] No significant changes have been reported in protein or casein content.

Overall, the impact of electromagnetic fields on milk composition appears to be limited.

Table 2 provides an overall summary of behavioral, physiological, reproductive, and milk production findings reported in relation to low-frequency electromagnetic field exposure in cattle farms. Most results are inconsistent, and the described changes are generally small and temporary.

Table 2 General summary of research findings on Electromagnetic Field (EMF) exposure in cattle farms

Topic	General findings	Reported field levels (μT)	Key references
Behavior	Mild restlessness, short-term avoidance, slight changes in orientation; findings are inconsistent.	0.5–5 μT (near equipment)	Marino et al.[7]; Rahmani & Johnson[13]; Cestnik et al.[14]
Physiology	Small and temporary fluctuations in hormones (melatonin, prolactin, progesterone); no major health effects.	1–10 μT (near panels/motors)	Burchard et al.[11]; Löscher & Mevissen[4]
Reproduction	No significant effects on estrous cycle, conception rate, or fertility.	Low field levels	Algers & Hultgren[24]; Burchard et al.[44]
Milk Yield	Some studies report slight changes but results are inconsistent; no strong effect.	0.5–10 μT	Burchard et al.[11]; Rahmani & Johnson[13]
Milk Composition	Minor changes in milk fat and lactose; most studies find no significant differences.	Low–moderate levels	Marino et al.[7]; Löscher & Mevissen[4]; Burchard et al.[11]

Table 3 presents commonly measured equipment that generates low-frequency electromagnetic fields in cattle operations.

Table 3 Main equipment generating Electromagnetic Fields (EMF) in cattle farms

Equipment/Point	Type of EMF source	Description
Electrical Panel	Low-frequency magnetic field	One of the locations where the highest measurements are commonly recorded.
Milking Motor	Magnetic field + current flow	May cause short-term field increases during its operating cycle.
Vacuum Pump	Magnetic field	Creates continuous low-level fields due to motor structure.
Fans	EMF from electric motor	Large fans may increase field intensity.
Automatic Drinker	Electrical connection	Occasional, low-level source of EMF.
Lighting Units	Electrical circuit	Generally low-intensity fields.

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Magnetic fields distribution within livestock facilities

In three field studies conducted by Bingöl et al. in different types of livestock operations, the levels of electromagnetic fields within the facilities were evaluated. These studies, carried out in poultry, goat, and cattle farms, revealed the distribution patterns of low-frequency magnetic fields in operational environments. In the poultry facility, measurements were taken at fifteen different points with three repetitions at each point, and most field intensities were reported to range between 0–20 μT.[26] Only one location showed a higher value, which was associated with the concentration of equipment in that area. Overall, the magnetic field intensity in the poultry facility was found to be low. In the goat facility, measurements were taken at eleven different locations, and field intensities were found to vary between 1.05–28 μT.[27] Higher field intensities were observed near the milking system and control units, and areas around motors and pumps showed higher magnetic fields compared to other sections. These results indicated that magnetic fields in intensive goat production systems are not distributed homogeneously. In the cattle facility, measurements were conducted at twenty-five points with three repetitions each, and most values ranged between 0.2–20 μT.[28] A single high value shown in the analysis table was classified as an outlier because it was not confirmed by field measurements. In general, magnetic field levels in the cattle facility were found to be low, with higher intensities occurring near equipment.

When these three studies are evaluated together, it becomes evident that electromagnetic field exposure remains low across different production systems; however, field intensity increases markedly in areas close to equipment such as motors, panels, and pumps. The findings suggest that, regardless of production type, magnetic field distribution is strongly associated with equipment density.

Discussion

This review shows that electromagnetic field (EMF) exposure in cattle farms is generally low and does not cause a clear negative effect on behavior, physiology, reproduction, or milk yield. However, not all results point in the same direction. Some studies have reported short-term restlessness, changes in orientation, or mild hormonal fluctuations, especially in areas with high equipment density.[4,7,11] These changes are mostly temporary and not severe enough to negatively affect the animal's health status.

Because behavior responds quickly to environmental changes, many EMF-related findings have been described through behavioral indicators. Short-term avoidance and mild restlessness have been reported around electrical panels, motors, and milking units where values of 1–5 μT were recorded.[12,14] Similar findings have also been reported near high-voltage transmission lines, where natural alignment behaviors can be disrupted.[5,6] However, differences between farms make it difficult to determine whether these behavioral changes are directly caused by EMF or by environmental factors.

Physiological findings show that small changes in hormones such as melatonin, prolactin, and progesterone can occur, but there is no strong evidence that these changes impair reproductive performance.[4,11] Most studies have not reported significant alterations in hematological or biochemical parameters.[13] This suggests that low-level magnetic fields do not create persistent physiological stress in cattle.

Findings related to milk yield and milk composition follow a similar pattern. Most studies indicate that EMF exposure does not cause a meaningful change in milk yield.[11] Small variations observed in milk fat or lactose levels are not consistent across studies.[4,7] Although some reports describe slight increases in somatic cell count, these results have not been reliably repeated.[13]

Field measurements are also consistent with the literature. In three different farms, the distribution of magnetic fields was closely related to equipment density, with the highest values recorded near panels, motors, and pumps.[26–28] This indicates that EMF levels are not homogeneous within the facility and vary depending on location.

Overall, most studies report that EMF does not have a strong impact on cattle health or performance. However, differences in farm infrastructure and measurement methods can lead to variation in results. The fact that exposure duration is not applied consistently across studies also contributes to these inconsistencies. Therefore, future research should adopt a more integrated approach that evaluates behavior, physiology, reproduction, and milk yield simultaneously and includes long-term observations.[29–35]

Conclusion

Overall, the studies reviewed indicate that electromagnetic field levels in cattle farms are generally low and do not produce substantial behavioral, physiological, reproductive, or production-related effects in animals. Although a few investigations have reported mild restlessness, minor hormonal changes, or limited variations in milk composition, these findings are inconsistent and largely attributable to differences in exposure duration, equipment density, measurement protocols, and farm design. Field measurements further show that magnetic fields are not uniformly distributed within facilities, but vary according to the proximity to electrical equipment. Given the variability and limited generalizability of existing results, especially across different species and production systems, further integrated and systematically designed studies are required to clarify the potential effects of electromagnetic field exposure in livestock.

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Conflicts of interest

The authors declare no conflicts of interest.

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