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Variation of magnetic field values at different locations in an intensive goat farm

Abstract

The occurrence of electromagnetic fields (EMF) in animal housing is a hidden environmental stress factor arising from the electrical equipment and infrastructure used in modern production systems. In particular, automatic feeding systems, milking machines, ventilation fans, lighting installations, and high-voltage lines in intensive goat, cattle, and sheep farms lead to the formation of electric and magnetic fields.

Since electromagnetic fields can induce electric currents and fields within the tissues of exposed organisms, EMF is considered a potential hazard to human and animal health. This situation has led to an increasing number of studies investigating the biological effects of electromagnetic fields.

This study aimed to determine the electromagnetic field (EMF) levels in an intensive dairy goat farm and to evaluate the possible effects of the fields to which the animals were exposed on milk and meat production as well as on animal health. Measurements were carried out at 11 locations representing different functional areas of the farm, with three replications at each point. The magnetic field intensity was found to range from 1.05 to 28.00 µT.

Analysis of variance (ANOVA) revealed statistically significant differences among the locations ($p < 0.05$); the difference was particularly concentrated at locations 6, 8, 9, and 11, where high-current lines and motor equipment were present. The overall mean value was 10.11 µT, and it was determined that in some locations this value exceeded the recommended threshold of 1–10 µT proposed by ICNIRP (2010).

The results indicated that the electromagnetic field in intensive goat farms is not homogeneously distributed and that field accumulation occurs especially around the milking system and control units. This highlights the importance of regular monitoring of electromagnetic fields in terms of both animal welfare and production safety.

Keywords: electromagnetic field, goat farm, intensive, production, welfare

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Abbreviations: EMF, electromagnetic fields; ANOVA, analysis of variance; PEF, pulsed electric field; PEMF, pulsed electromagnetic field

Introduction

Goats have a distinctive morphological and behavioral structure. This species, which is more agile, resilient, and has a well-developed climbing ability, can be easily recognized by its slender and backward-curved horns and its short, upright tail. Behaviorally, goats are curious and individualistic, with weaker flock bonds compared to sheep. They are also selective grazers; by consuming leaves, twigs, and shrubs, they are able to utilize low-quality pastures. Due to these characteristics, they can easily survive in desert, mountainous, and semi-arid regions.[1]

Goats (*Capra hircus*) were domesticated approximately 10,000–11,000 years ago in the Middle East, in the region known as the "Fertile Crescent," from the wild Bezoar goat (*Capra aegagrus*).[2,3] Today, they are widely raised around the world for milk, meat, and fiber production. Their small body size, adaptability to harsh environmental conditions, and high reproductive capacity provide an economic advantage, especially in mountainous and arid areas (Figure 1).[1]

Goat milk is easily digestible due to its small fat globules and medium-chain fatty acids and is particularly recommended for children, the elderly, and individuals with digestive sensitivity.[4,5] The concept of welfare in goats refers to a production environment in which the animal is healthy, free from stress, able to express its natural behaviors, and lives in harmony with its surroundings.

Figure 1 A view from the goat farm where the study was conducted.

However, the growing food demand of the increasing population has led to the widespread adoption of intensive production systems. In these systems, limited space, artificial environmental conditions, and the intensive use of electrical equipment increase the environmental stress factors that may affect animal welfare. In particular, the electromagnetic field (EMF) that occurs in barns is a hidden stress factor arising from the equipment and electrical infrastructure used.

In intensive goat, cattle, and sheep farms, automatic feeding systems, milking machines, ventilation fans, lighting installations, and high-voltage lines cause the formation of electric and magnetic fields. It has been reported that low-frequency (0.1–100 Hz) and low-intensity (0–100 µT) fields do not have a directly harmful effect on metabolism and hormonal balance and may even have beneficial effects at appropriate levels.[6–8] Controlled EMF applications have been reported to improve milk and meat quality; however, continuous exposure may trigger stress responses.[9]

Therefore, determining the effects of electromagnetic fields on animal welfare and production parameters is of great importance. In this study, it was aimed to measure the electromagnetic field (EMF) levels in a goat farm operating under intensive conditions, to identify potential high-field regions, and to evaluate the results in terms of sustainable production.

Materials and methods

This study was conducted in an intensive goat farm. Measurements were carried out at locations representing different functional areas of the farm. Three replicate measurements were taken at each location to increase the reliability of the results.

In this context, the pulsators, vacuum pump, control panels, milking washing unit, transformers, motor, and main control unit located in the milking parlor were evaluated. The measurement locations included the pulsator, main control unit, transformer line, milking washing unit, vacuum pump control point, control panel, and the area surrounding the vacuum pump.

In the study, a Smart Sensor AS1392 EMF meter was used for magnetic field measurements (Figure 2). This device is suitable for measuring low-frequency electromagnetic fields, with a measurement range of 0–200 µT, a resolution of 0.1 µT, and an accuracy of ±5%. It operates in a 30–300 Hz frequency range and provides reliable data with an approximate sampling time of 0.5 seconds. During the measurements, the device was calibrated according to the manufacturer's procedures, and the batteries were regularly checked to ensure uninterrupted fieldwork (Figure 3).

Figure 2 Measurement points in the intensive goat farm.

At each location, the device was positioned both at ground level and at human height for measurements. In this way, both the exposure at the level of the animals and the possible exposure of the workers were evaluated. The recorded values were converted to microtesla (µT), and for each location, the mean, minimum, and maximum values were calculated.

Figure 3 Magnetic field measuring device.

In the statistical analysis of the data, descriptive statistics (mean, standard deviation, minimum, and maximum) were first calculated. One-way analysis of variance (ANOVA) was applied to determine the differences between locations. The Duncan multiple comparison test was performed to identify from which locations the differences originated. In addition, outliers observed in the measurements were evaluated, and their effects on the statistical results were considered.

The analyses were performed using the SPSS 28.0 statistical package program, and the level of statistical significance was accepted as $p < 0.05$.

Results and discussion

In this study, magnetic field measurements taken at 11 different locations in the intensive goat farm were evaluated. Descriptive statistics of the measurement results are presented in Table 1. The values were found to range between 1.05 and 28.00 µT. The variance analysis revealed that the differences in electromagnetic field measurement results among the locations in the goat farm were statistically significant.

The overall mean value was determined as 10.11 µT. The lowest value was measured as 1.05 µT at location 2 (Main control unit), and the highest value was measured as 28.00 µT at location 6 (Control panel). The ICNIRP[10] reported the electromagnetic field limit as 1–10 µT. According to the measurement results, five locations in the farm were within this threshold, while six locations exceeded the limit value.

These findings are consistent with the results reported by Bingöl et al.,[11] who found that electromagnetic field levels increased in areas where power lines were concentrated in measurements taken at different locations in a dairy cattle farm. In the present study as well, the field intensity was found to increase significantly at locations 6, 8, 9, and 11, while remaining at lower levels in the other locations ($p = 0.003$) (Figure 4).

In this study, the ANOVA analysis revealed statistically significant differences among the locations ($p < 0.05$). According to the Duncan test results, the differences were mainly concentrated at locations 6, 8, 9, and 11. The common feature of these measurement points is that they are areas where high-current-carrying lines and motor equipment are located. Therefore, the high average values measured in these regions are thought to result from increased electrical loading and magnetic field concentration.

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Table 1 Magnetic field measurement results at different locations of the intensive goat farm

Location no	Measurement point name	Mean (µT)	Std. Deviation (µT)	Std. Error (µT)	Minimum (µT)	Maximum (µT)
1	Pulsator	1.63	0.49	0.29	1.23	2.18
2	Main control unit	4.86	3.97	2.29	1.05	8.97
3	Transformer line	5.97	3.29	1.9	3.2	9.6
4	Milking washing unit	3.49	2.47	1.43	1.3	6.17
5	Vacuum pump control point	5.08	3.28	1.89	1.61	8.13
6	Control panel	16.22	10.95	6.32	6.35	28
7	Vacuum pump	12.19	4.09	2.36	9	16.81
8	Motor area	15.13	1.46	0.84	14.1	16.8
9	Milking room line	15.63	8.66	5	9.29	25.5
10	Electrical panel area	12.67	3.67	2.12	9.8	16.81
11	Transformer output line	18.33	3.6	2.08	14.81	22
Overall mean	—	10.11	7.16	1.25	1.05	28
Significance level (p)	—	0.003				

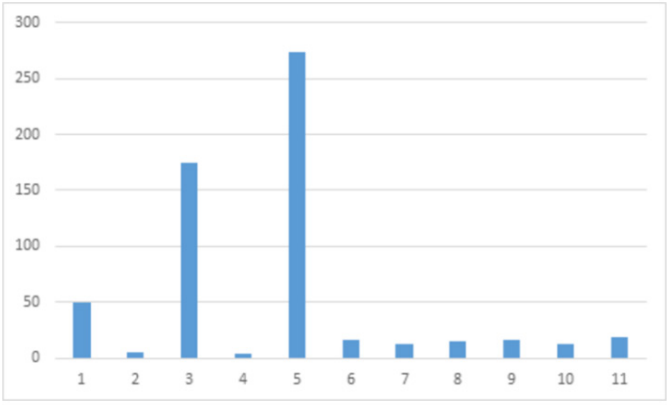

Figure 4 Mean magnetic field values (µT) at different locations in the intensive goat farm.

This result indicates that the magnetic field within the farm is not homogeneously distributed and that field accumulation occurs at certain points. Such variations in field intensity are closely related to equipment placement and the direction of electrical wiring.

The occurrence of high values at some locations revealed the presence of regions with increased electrical intensity within the farm. This situation can be associated with the continuous operation of equipment and the concentration of power distribution along certain lines in intensive production systems. In particular, higher field intensities are expected in areas where motorized systems are densely located. The selected measurement points were determined to represent these zones of different electrical intensity within the farm.

Locations 1–5 (Pulsators): The average values ranged between 1.23–8.13 µT. Noticeable differences were observed among the three repeated measurements taken on the same pulsator. Some measurements showed lower, while others showed higher magnetic field values. This situation results from the operation principle of pulsators, which work based on the vacuum cycle. During the vacuum application phase, the direction of the current and the pressure increase, causing a momentary rise in the magnetic field. In the release phase, the pressure decreases and the magnetic field intensity is reduced. Since pulsators in small ruminant milking systems operate in shorter cycles, instantaneous changes in the magnetic field can occur between measurements.[12,13]

The operating mechanism of pulsators used in small ruminant milking systems differs significantly from those used in large ruminant systems. In goats, the suction and release cycle occurs in a shorter time, resulting in more frequent electromagnetic fluctuations generated by the pulsator. Studies in the literature report that an increase in pulsation frequency and vacuum fluctuations raises the electrical load.[13,14] In large ruminant milking systems, the average pulsation frequency is 60–90 cycles per minute, while in goats this value ranges between 120–180 cycles per minute.[12] This difference causes more frequent current fluctuations in small ruminant milking systems, leading to an increase in magnetic field intensity.

Although electromagnetic fields were not directly measured in these studies, it can be physically inferred that an increase in electrical cycle speed may influence magnetic field intensity.[12–14] In the present study as well, the lower average values measured in the pulsator area compared to other locations may be due to the shorter and intermittent operation cycles of motors in small ruminant milking systems. The fact that field intensity was concentrated mainly around control units and pumps explains this difference. Moreover, this result indicates that electromagnetic fluctuations during the milking process may indirectly affect animal behavior and comfort.

Location 6 (Main control unit): With an average of 16.22 µT, this is one of the highest magnetic field values measured in the farm. This location is the area where electrical distribution is most concentrated. The proximity of high-current-carrying cables and metal surfaces causes an increase in the magnetic field. Such areas generally constitute the energy center of the farm, and the continuous flow of power leads to a permanently high field intensity.

Location 7 (Transformer): The average value was 12.19 µT. Since the transformer line serves as an energy conversion point, the field intensity is high. This value indicates that the magnetic field around the transformer can spread over a wide area.

Location 8 (Milking wash unit): The average value was 15.13 µT. In this section, the field intensity increases due to continuously operating motors and heating equipment.

Location 9 (Vacuum pump control unit): The average value was 15.63 µT. The high current passing through the control systems in this area has increased electromagnetic loading.

Location 10 (Control panel): The average value was 12.67 µT. It was observed that the magnetic field increases around electrical panels and connection points.

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Location 11 (Vacuum pump): The average value was 18.32 µT, which is the highest value measured in the farm. This location represents the area where the motors remain continuously active during milking and where electrical loading is the most intense. The long operating time of the motors causes an increase in magnetic field intensity. These continuously running motors generate a strong magnetic field in the environment, and the weakening of this field is only possible when the system is shut down.

The obtained results are also consistent with the findings reported in the literature regarding the possible effects of electromagnetic fields on livestock production systems. Studies have shown that EMFs, particularly low-frequency electric and magnetic fields, influence animal physiology, milk yield, and meat quality.[7–9,15,16]

For example, Li et al.[7] demonstrated that the electromagnetic preservation method in *Guizhou black goat* meat was more advantageous than frozen storage in maintaining color, water-holding capacity, and aroma characteristics during the storage period. Similarly, Lei et al.[15] reported that EMF applications in *Northern Qianbei Ma* lamb meat prevented pH increase, preserved color values (*a*, *b*), and improved meat tenderness. These findings suggest that electromagnetic preservation methods are more effective than traditional methods in extending meat shelf life and maintaining sensory quality.

In the field of meat technology, studies have shown that electromagnetic applications offer significant potential not only in preservation but also in processing stages. Jeong et al.[8] reported that *pulsed electric field (PEF)* applications reduced meat toughness by 35%, decreased microbial load, and improved chewing characteristics. This indicates that EMF technology can make important contributions to both product safety and consumer acceptance.

Wang et al.[16] emphasized that the combined use of superchilling technology with EMF has great potential for the future in terms of controlling protein and fat oxidation, suppressing microbial growth, and maintaining water-holding capacity.

In terms of milk production, electromagnetic applications have also been shown to create notable effects. Burchard et al.[6] observed no direct differences in milk yield or composition in their experiment with Holstein cows; however, they reported increases in dry matter intake, milk fat content, and plasma progesterone levels. These findings indicate that electromagnetic fields may indirectly support productivity.

Similarly, Young[9] stated that *pulsed electromagnetic field (PEMF)* therapy improved milk yield and composition in organic dairy cows and also supported the animals' biological recovery processes. Although some studies have not identified clear differences,[6] others have reported positive results, particularly in quality parameters and biological recovery.[7–9,15,17,–34]

Conclusion and recommendations

In general, the obtained findings can serve as a reference for future studies aiming to evaluate the relationship between electromagnetic fields and productivity.

Most of the measurement points are within safe limits; however, attention should be paid to locations 6 and 11 due to their high values.

The magnetic field in these areas may represent a potential stress source for goats exposed for extended periods.

Field intensity can be reduced by rearranging cable layout, grounding, and equipment distances.

Measurements should be repeated at different periods to monitor seasonal variations and equipment loading.

In future studies, the relationship between current fluctuations and magnetic field intensity should be directly measured to establish safe threshold values for intensive goat farms.

These results indicate that differences such as farm location, level of technological use, equipment characteristics, EMF type, application intensity, and duration are decisive factors influencing the outcomes. Therefore, future studies should employ standardized experimental designs to more clearly reveal the effects of EMF under different animal species and production conditions.

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Conflicts of interest

The authors state that there is no conflict of interest.

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