The 1st
International Vocational Agriculture Symposium
Volume 1 Nomor 1 April 2026

Development of Internet of Things (IOT) Technology For Health Monitoring in Goats : A Review

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History Article:
- Submit: August 2025
- Publish: April 2026

Keyword:
Environmental sensors, Livestock welfare, Real-time, Smart farming, Wearable sensors

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Abstract
Internet of Things (IoT) technology provides a significant innovation in real-time goats health monitoring, replacing less responsive and accurate conventional methods. In traditional livestock farming, delayed disease detection often leads to livestock deaths and reduced productivity. IoT utilizes wearable sensors that measure body temperature, heart rate, and physical activity, as well as GPS sensors to monitor livestock movement. The collected data is analyzed with machine learning algorithms to detect early signs of disease, enabling faster intervention. Acoustic and environmental sensors, which measure temperature, humidity, and ammonia, complement the monitoring, providing a comprehensive picture of livestock and environmental conditions. This data integration supports more precise and efficient farm management, improving productivity and goats welfare, while reducing costs and environmental impact. Furthermore, IoT technology can be applied with smart surveillance cameras (CCTVs) equipped with temperature sensors to non-invasively monitor animal body temperature and automatically monitor pen conditions. Review discusses the stages of IoT development, including hardware design, cloud platforms, machine learning algorithms, and field testing. Results demonstrate high accuracy and ease of implementation. Recommendations for development include sensor improvements, scalability, user training, and policy support and cross-disciplinary collaboration to ensure the sustainability of the technology in the national livestock sector.

INTRODUCTION

The development of Internet of Things (IoT) technology has brought revolutionary changes in various aspects of life, including the livestock sector. IoT technology plays a crucial role in modern livestock management, especially in enhancing the efficiency of real-time animal health monitoring. In the context of goat farming, this technology enables continuous data collection and processing that was previously difficult to achieve using

conventional methods. Goats are a valuable commodity widely raised by small to medium-scale farmers and serve as a primary source of animal protein and a pillar of rural economy. With this technology, goat health monitoring activities can be performed more efficiently and accurately to maximize livestock productivity (Morrone et al., 2022; Bernabucci et al., 2025).

The implementation of IoT technology in goat farming encompasses not only physical health measurements but also behavioral and environmental aspects that affect the overall health of the animals. Traditionally, farmers rely heavily on manual inspections which depend greatly on experience and are often less responsive to subtle changes in goat conditions. Early intervention in health issues is vital for successful management and preventing disease spread among livestock. By utilizing smart sensors attached to the goats and their environment, monitoring can be carried out continuously, and health data can be collected without disruption, addressing the limitations of conventional methods (Rao et al., 2020; Gonçalves et al., 2024).

The utilization of IoT also involves wearable devices that measure various physiological parameters such as body temperature, heart rate, and activity levels. These sensors operate within an ecosystem connected through wireless communication networks, enabling direct data transmission to a central monitoring system. This technology allows the early detection of abnormal conditions such as fever, stress, or reduced activity, which usually indicate illness. The system also employs machine learning algorithms to capture critical patterns that might be missed by human observation, thus improving diagnostic accuracy and enabling early intervention (Zhang et al., 2021; Pardo et al., 2022).

Furthermore, IoT provides information on the environmental conditions surrounding the goats, including air temperature, humidity, air quality, and ammonia levels. These factors are important because unfavorable environmental conditions can worsen goat health and trigger respiratory diseases and other infections. Integrating environmental data with physiological data allows farmers to understand the interrelation between internal animal health and external environmental factors. Monitoring environmental conditions also helps optimize barn management and grazing areas to reduce disease risks caused by adverse environments (Ntalampiras et al., 2023; Ding et al., 2025).

IoT-based technology also incorporates acoustic sensors to capture goat sounds. Sound analysis is useful for detecting health disturbances, such as coughing and abnormal vocalizations that may indicate respiratory infections. These sensors are equipped with sound processing systems that differentiate between normal and abnormal sounds. This way, besides monitoring physical and behavioral aspects, the system provides passive monitoring without disturbing the goats' daily activities, offering a comprehensive picture of animal welfare (Ntalampiras et al., 2023; Ding et al., 2025).

Beyond raw data, the IoT platform is equipped with cloud technology so that data from various sensors can be stored and analyzed using advanced algorithms. The use of cloud technology facilitates data access by farmers, veterinarians, and researchers via mobile devices and computers in real-time from any location. The applied machine learning algorithms can not only identify deviations from healthy conditions but also provide action recommendations based on historical data and field conditions. This promotes quick, accurate decision-making based on scientific evidence that supports sustainable goat health management (Gonçalves et al., 2024; Mishra et al., 2023).

At the behavioral level, integrated accelerometer and GPS data monitor not only physical health but also provide information about movement patterns, social interactions, feeding behavior, and resting time. These behavioral patterns are vital early indicators of health problems since goats typically change their behavior before showing clinical symptoms. Spatial data on goat movement also assists in managing grazing land to prevent overgrazing and optimize grazing rotations accurately. Thus, IoT strengthens the concept of

Precision Livestock Farming aimed at simultaneously improving productivity and animal welfare (Méndez et al., 2025; Taer et al., 2025).

Another advantage of IoT technology is the ease of information access and remote monitoring through mobile applications and web-based dashboards. Farmers and veterinarians can monitor goat conditions in real-time even when they are in different locations. Early warnings and automatic notifications for abnormal conditions allow systematic and rapid response, reducing the risk of greater losses. Field trials of IoT implementations in goat farms have shown promising results in improving monitoring efficiency, reducing mortality rates, and easing management for various scales of goat farming operations (Zhang et al., 2021; Schulthess et al., 2024).

In addition to wearable and environmental sensors, smart monitoring technology using thermal cameras is increasingly adopted to complement livestock health monitoring. Thermal cameras can detect surface body temperature of goats non-invasively and can reveal subtle changes indicating early inflammation or fever. Integration of thermal cameras with other sensors improves detection accuracy and allows for a more holistic evaluation of animal welfare. This technology also has the potential to reduce stress caused by manual inspections, while lightening the workload of farmers and increasing operational efficiency (Bernabucci et al., 2025; Kumar & Singh, 2022).

Thus, the development of IoT technology leads to a paradigm shift in goat health management from reactive approaches to more proactive and preventive ones. This system enables early detection and rapid intervention through comprehensive and accurate data on physiological, behavioral, and environmental conditions. Not only does it reduce treatment costs and increase productivity, but it also aligns with sustainable farming practices through optimized resource use and animal welfare. To realize wide and effective adoption of IoT, supportive policies, farmer training, and multidisciplinary collaboration between technology, animal health, and agribusiness sectors are essential (Pardo et al., 2022; Terence et al., 2024).

RESEARCH METHODOLOGY

This study was conducted with the objective of compiling and critically analyzing various scientific articles relevant to methods for detecting Fasciolosis infection. The data used in this research were entirely secondary sources, consisting of previously published scientific works such as international journals, conference proceedings, and research reports, which were re-examined through a systematic review approach. References were collected in a structured manner using academic databases and online platforms such as Google Scholar and ResearchGate. To ensure the relevance and accuracy of the search results, specific keywords were applied, including “goat,” “internet of things,” “health monitoring,” and “smart farming,” selected based on their direct relation to the research topic. The literature search was limited to the publication period from 2020 to 2025, ensuring that all references used represent recent studies aligned with technological developments and contemporary livestock health issues.

The data collection process began on September 26, 2025, and was carried out gradually. Each identified publication was evaluated in terms of methodological quality, relevance to the research focus, and its contribution to the understanding of IoT-based technology utilization in monitoring goat health. Through this approach, the study aims to achieve high accuracy and provide a comprehensive overview of the advancements in disease detection methods within the smart farming sector.

RESULTS AND DISCUSSION

The development and implementation of Internet of Things (IoT) technology in monitoring goat health have become a significant milestone in the modernization of global livestock systems. IoT functions not only as an automated monitoring tool but also as the foundation of an intelligent management system that integrates digital technology with traditional farming needs. This technology provides accurate real- time solutions with measurable and reliable data, enabling the modernization of livestock systems alongside improved efficiency and productivity. IoT connects lightweight and ergonomic smart sensors, energy-efficient wireless data communication systems, and artificial intelligence analytics that process animal health information comprehensively and rapidly. As a result, management paradigms have shifted from slow, error-prone manual methods to responsive and precise automated systems. This allows farmers to understand the condition of their livestock in detail and perform timely interventions as needed. The direct impact is seen in improving goat welfare and supporting sustainable and environmentally friendly farming practices (Morrone et al., 2022; Bernabucci et al., 2025).

IoT technology enables continuous and automated monitoring of goat health without requiring the farmer's constant physical presence. Through interconnected sensor networks, physiological data such as body temperature, heart rate, and activity patterns, as well as environmental data such as air temperature, humidity, and ammonia levels, are collected in real time. This data is processed using machine learning algorithms to produce a comprehensive overview of the health of individual goats and the entire herd. Farmers can access a digital dashboard platform to monitor livestock conditions and receive early notifications when anomalies are detected. This approach allows faster interventions, reduces delays in disease management, and enhances operational efficiency on the farm. The transformation of management systems from reactive and manual to proactive and predictive significantly improves production outcomes. The system also supports long-term health trend analysis, taking into account the effects of climate change on goats (Rao et al., 2020).

Smart wearable sensors attached to goats' bodies record various vital parameters such as temperature, heart rate, and daily activity patterns with high accuracy. These sensors are ergonomically designed to be lightweight and comfortable, preventing stress during use. Non-invasive thermal cameras are also used to detect surface temperature fluctuations that indicate infection or heat stress. Sensor data are transmitted via energy-efficient communication networks such as LoRa, ZigBee, or GSM, operating continuously for months in farms without direct access to electricity. The data stored in the cloud are analyzed using artificial intelligence to identify and alert abnormal behavioral or physiological patterns in goats. Through this integrated technological system, decision-making can be carried out adaptively to optimize nutritional and environmental management. This greatly contributes to the overall health, welfare, and productivity of goats (Kumar Singh, 2022; Gonalves et al., 2024; Mishra et al., 2023).

Livestock Management Transformation

IoT technology enables automatic and continuous monitoring of goat health without requiring the farmer's constant physical presence in the field. Through interconnected sensor networks, various physiological information such as body temperature, heart rate, and activity levels can be collected in real time. In addition, environmental data such as air temperature, humidity, and ammonia concentration are continuously monitored. This data is then processed using advanced machine learning algorithms to provide an accurate picture of the health status of individual goats as well as the herd collectively. A digital dashboard-based visualization platform allows farmers to receive notifications and early warnings so that actions can be taken quickly before diseases become severe. This digital transformation changes livestock

management into a scientific and systematic data-based approach, no longer relying solely on experience or intuition. As a result, farm operational efficiency and productivity can be maximized without increasing the labor burden (Morrone et al., 2022; Bernabucci et al., 2025; Sibarani & Rismawan, 2024).

This IoT approach replaces reactive manual monitoring with a proactive system based on data and predictions. Previously, monitoring goat health conditions was conducted periodically, requiring significant time and effort. Now, with IoT technology, monitoring is carried out automatically and accurately without direct human intervention at all times. Farmers can manage large-scale livestock populations more effectively because data is centralized and easily accessible via mobile or web applications. Stored historical data also helps predict health trends and disease patterns related to climate and seasonal factors. Thus, decision- making regarding feeding, treatment, and environmental management can be carried out more optimally and precisely. The system also helps minimize the risk of errors that often occur in traditional methods (Rao et al., 2020; Nugraha et al., 2024).

Wearable sensors and additional devices such as thermal cameras are crucial components in modern agricultural IoT systems. Wearable sensors are attached to the goats' bodies to record various vital indicators and daily behavior patterns, designed to ensure comfort without interfering with the animals' natural activities. Thermal cameras are used for non-invasive and rapid detection of surface body temperatures indicating infection or stress. Sensor data is transmitted via energy-efficient wireless networks such as LoRa, ZigBee, and GSM, which operate reliably under challenging field conditions. Real-time data processing with the assistance of artificial intelligence generates information that can be directly applied to managerial decision-making. This helps farmers improve the health, welfare, and productivity of goats sustainably with the support of smart technology (Kumar Singh, 2022; Gonalves et al., 2024; Nugraha et al., 2024).

Smart Sensors and Communication Technology

Smart wearable sensors attached to the neck, legs, or body of goats are capable of real-time monitoring of various vital parameters such as body temperature, heart rate, daily activity patterns, as well as feeding and drinking behavior. These sensors are ergonomically designed to be lightweight and unobtrusive to avoid disturbing the goats' natural behavior and to prevent additional stress. Besides body-worn sensors, thermal cameras have recently been applied to detect fluctuations in the surface temperature of livestock non-invasively. This technology helps early identification of health issues such as infections or inflammations. The data collected from these sensors are transmitted via energy-efficient and long-lasting wireless communication networks such as LoRa, ZigBee, and GSM, which operate reliably for several months in farm environments lacking electricity access (Kumar Singh, 2022; Gonalves et al., 2024).

The collected data is uploaded to local or global cloud platforms where advanced machine learning algorithms analyze it to recognize normal patterns and detect anomalies indicative of possible health problems. This integration of IoT sensors with AI-based analytics enables adaptive decision-making based on accurate data. Such decisions inform the regulation of nutrition and environmental conditions to ensure goats are raised under optimal circumstances that promote health and productivity. This technological synergy contributes significantly to improving welfare and performance in goat farming operations. Furthermore, it removes the reliance on subjective human observations, allowing for continuous, objective monitoring (Mishra et al., 2023; Kumar Singh, 2022).

Wireless communication technologies like LoRa, ZigBee, and GSM are crucial components of smart farming systems, especially in rural and remote areas. These networks offer low-power, wide-area coverage, facilitating steady and cost-effective data transmission

from sensors scattered across extensive farm lands. Their long battery life and robust signal enable months of uninterrupted monitoring even under challenging weather and terrain conditions. Cloud connectivity further enables farmers and managers remote real-time access to herd health data, improving responsiveness and decision-making speed. This setup also provides opportunities for centralized data storage and analysis, fostering data-driven improvements in farm management. Secure wireless communications ensure data integrity and protection against cyber threats, which is increasingly important as digital farming scales up (Gonalves et al., 2024; Mishra et al., 2023).

The ergonomic design of the wearable sensors ensures that animals experience no stress or disruption in their natural activities, which is essential for accurate behavior and health data collection. Sensors continuously track physiological signals that can be early indicators of stress, illness, or discomfort before visible symptoms appear. Thermal imaging adds another layer of health assessment by detecting subtle temperature changes suggestive of localized infections or inflammation. Together, these tools provide a comprehensive health overview that aids veterinarians and farmers in proactive animal care. With the data analytics capabilities, it becomes possible to optimize feeding regimes, minimize health risks, and improve overall farm productivity. The combination of technology and animal welfare principles makes smart farming both effective and ethical (Kumar Singh, 2022).

Finally, the adoption of smart sensors and IoT communication technologies is transforming traditional goat farming into precision livestock management. This approach brings enormous benefits including higher productivity, improved animal welfare, and more sustainable farming practices. Digital platforms based on cloud computing and AI allow for scalable, customizable farm management tailored to specific herd needs and environmental conditions. As technologies evolve, the cost of implementation is gradually decreasing, making these benefits accessible to a growing number of farmers worldwide. The ongoing innovation and integration of technology promise to radically enhance the future of goat farming globally (Gonalves et al., 2024; Mishra et al., 2023).

Environmental Monitoring and Animal Welfare

In addition to monitoring the physiological condition of goats, Internet of Things (IoT) technology also plays a vital role in automatically and continuously monitoring the quality of the barn environment. Installed environmental sensors can measure various important parameters such as barn temperature, air humidity, ammonia gas concentration, and dust levels, which significantly impact the health of goats' respiratory systems. Poor and poorly monitored environmental conditions can lead to serious problems such as heat stress, respiratory disorders, and even a significant decrease in livestock production efficiency. With real-time data monitoring, IoT systems can immediately activate automated mechanisms such as ventilation, cooling mist systems, or clean the barn as needed without human intervention. This allows farmers to consistently maintain optimal barn comfort and conditions, thereby reducing the risk of environmental diseases. Studies at Arjuna Farm, for example, demonstrated the success of real-time monitoring of temperatures between 25-50°C and humidity up to 99% with the integration of IoT sensors, which helped increase dairy goat productivity while maintaining animal health (Wong, 2025; Zhang et al., 2021; Pardo et al., 2022). This technology is an important foundation in the concept of smart farming which is developing rapidly and is relevant to future challenges.

A healthy and well-maintained barn environment also impacts the lifespan of goats and the quality of products like milk and meat, which must meet stringent health standards. IoT sensors can provide early warnings of extreme temperature and humidity fluctuations that can worsen livestock conditions and cause stress. With a holistic approach that integrates environmental and animal health data, this IoT- based monitoring system supports efforts to

create an environmentally friendly and sustainable livestock ecosystem. This is crucial amidst the challenges of climate change and natural resource degradation that impact all aspects of livestock production. Furthermore, continuous monitoring helps optimize barn infrastructure management to maintain optimal condition and extend the economic lifespan of livestock. Numerous studies and real-world applications demonstrate the effectiveness of this technology in improving the operational efficiency of goat farms. The implementation of IoT in barn environmental monitoring is a strategic step towards digital transformation in the modern livestock world (Nugraha et al., 2024; Telkom University, 2025; Jember State Polytechnic, 2024).

Intelligent Analytics and Disease Prediction

Processing big data generated from sensors in IoT systems using machine learning technology enables high-precision classification of goat activity. Activities such as eating, resting, walking, and rumination can be identified automatically and continuously using intelligent algorithms that learn the normal behavioral patterns of each individual and the population as a whole. By understanding these patterns, the system can identify behavioral anomalies that indicate health problems earlier than conventional manual inspection methods. The availability of this detailed data opens opportunities for farmers to take timely, evidence-based action. Furthermore, processing big data enables comprehensive goat health evaluation by integrating various interrelated data sources (Zhang et al., 2021).

Machine learning's ability to recognize goat behavioral patterns facilitates early disease prediction by combining physiological, behavioral, and environmental data. The complex correlation between these data allows for more accurate diagnoses and preventative treatment, thus reducing mortality and productivity decline in livestock. One advantage of this technology is its ability to provide early notification so that medical or managerial actions can be implemented immediately. This approach saves costs and time and reduces the risk of disease spread within the broader goat population. This intelligent health monitoring supports more responsive and efficient livestock management (Schulthess et al., 2024).

In addition to activity classification and disease prediction, artificial intelligence in IoT systems also supports the development of precision health models that can be tailored to the specific needs of goat populations. These models consider the animals' genetic makeup, environmental factors, and even their diets to provide highly personalized and adaptive recommendations. An example is the development of a heat stress model that anticipates risks during the dry season, allowing the system to automatically activate cooling devices to maintain the goats' physiological health. Such adaptive models enable farms to operate optimally under varying climatic and environmental conditions. This big data- and machine learning-driven approach represents the future of sustainable livestock management (Zhang et al., 2021).

The use of IoT technology supported by artificial intelligence also benefits livestock operational management. This integrated system provides real-time data that helps managers make decisions regarding feeding, environmental management, and medical care. With the support of predictive analytics, livestock planning and management become more effective and evidence-based. This also improves farmer performance by monitoring the health of hundreds to thousands of goats simultaneously, thereby increasing work efficiency and reducing manual workload. This entire process supports more consistent and high-quality livestock production (Rao et al., 2020).

Economic Efficiency and Operational Management

The positive impacts of implementing Internet of Things (IoT) technology on the economic aspects of goat farming are significant and diverse. First, with an early disease detection system, medical and labor costs can be significantly reduced because treatment can be administered before the disease spreads or the goats require intensive care. IoT technology enables real-time monitoring, allowing early disease detection, preventing further spread and reduced productivity. Second, a significant reduction in goat mortality helps increase farmers' net income and mitigates unexpected losses. Third, feed efficiency also increases because feeding can be adjusted to the actual needs of each goat, which is automatically monitored. Many studies show that the use of IoT can increase feed efficiency by up to 20% and reduce waste that is common in conventional livestock systems. Fourth, data collected by IoT systems is used in livestock product quality assurance and traceability systems, increasing consumer confidence and increasing livestock product sales value, especially in export markets that increasingly demand food safety and sustainability standards (Rao et al., 2020; Schulthess et al., 2024; Alfassa, 2025).

Furthermore, livestock operational management has become more efficient with the help of IoT technology. An integrated monitoring system allows for better management of feeding, environmental management, and simultaneous monitoring of livestock health. With automation technology, the workload of farmers can be reduced because many processes run autonomously based on real-time data and intelligent algorithms. This not only saves time but also reduces human error that can occur in manual management. This efficiency results in sustained productivity increases and lowers overall operational costs. This technology also enables farmers to manage large goat populations more easily and accurately. As a result, livestock business models are transforming to become more digital, efficient, and economically and environmentally sustainable (Nugraha et al., 2024; Ahmad et al., 2023; Rao et al., 2020).

Implementation Challenges and Sustainable Development Strategies

The implementation of Internet of Things (IoT) technology in goat farming still faces several complex and multidimensional challenges. One major obstacle is the cost of the necessary hardware and communication network infrastructure, which can sometimes be a significant burden for farmers, especially those in rural areas and small-scale businesses. Furthermore, limited or unstable internet and electricity networks also hinder optimal use in the field. These limitations often result in disruptions or delays in data transmission from sensors to the central server, thus hindering the optimal performance of the monitoring system. In addition to technical factors, data security is also a significant concern, as the collected data is sensitive and requires additional protection from cyber threats. This requires the development of systems that are not only efficient but also have robust security layers to ensure data reliability and prevent misuse. Therefore, large initial investments and inadequate infrastructure are significant obstacles to widespread IoT adoption in goat farming (Mishra et al., 2023; Akhigbe et al., 2021).

In addition to technical challenges, the design of devices used in the field must also be able to withstand harsh conditions and dynamic environments. Wearable devices installed on goats must be designed to withstand extreme weather, vibrations from goat activity, and be resistant to dust and high humidity. However, these devices must also remain lightweight and ergonomic to avoid disrupting the goats' well- being or natural behavior, thus preventing stress and affecting production yields. The development of long-lasting battery technology, the use of solar energy, and devices with intuitive user interfaces are crucial factors in supporting the

success of this implementation. Furthermore, device management and regular maintenance are essential to ensure the system remains optimally functional over the long term. Design errors or unreliable devices can lead to monitoring failures and undermine farmer confidence in the technology. Therefore, research and innovation in hardware and software specifically for open farm environments is a major focus today (Mishra et al., 2023; Telkom University, 2025).

Another often overlooked challenge is the non-technical aspects related to the skills and knowledge of farmers. Many farmers, particularly in rural areas, still have limited technological literacy and therefore require ongoing training and mentoring to effectively utilize IoT technology. Resistance to change and fear of losing control over traditional production systems are also significant social barriers. Therefore, government support in the form of clear policies, financial incentives, equipment subsidies, and technology education programs is essential to accelerate the adoption of IoT policies among farmers. Close collaboration between researchers, the private sector, training institutions, and farmer communities is necessary to build an ecosystem that supports the sustainable development and utilization of this technology. With the right combination of technology and adequate human resource support, these challenges can be overcome, allowing IoT to provide maximum benefits to the goat farming industry (Terence et al., 2024; Alfassa, 2025).

Sustainability Prospects and the Digital Farming Ecosystem

The sustainability of the Internet of Things (IoT) in the goat farming sector depends heavily on the development of a holistic and integrated digital ecosystem. IoT, connected to various systems such as feed management, reproduction, environmental management, and logistics, creates a smart farm ecosystem that enables efficient and comprehensive farm management. The integration of data generated from these systems enables a smarter, real-time approach to livestock management. With this ecosystem, each stage of management, from upstream to downstream, can be continuously controlled and optimized to support effective production. This approach maximizes resource utilization through the use of appropriate and sustainable technology (Pardo et al., 2022; Wong, 2025; Zhang et al., 2021).

Big data collected from various sensors and IoT devices can also be analyzed to measure environmental aspects, such as the carbon footprint, water consumption, and energy used in livestock operations. This is crucial for assessing environmental impacts and helping farmers meet increasingly stringent global sustainability targets. Implementing sustainability-oriented smart farming principles is essential for livestock businesses to be not only productive but also environmentally friendly. Analysis of this environmental data can be used to optimize the use of production inputs and minimize waste or pollution. In this way, goat farming can positively contribute to climate change mitigation and natural resource conservation (Kumar Singh, 2022; Nugraha et al., 2024; Jember State Polytechnic, 2024).

More than just an operational tool, IoT in the era of smart agriculture provides sustainable resource management services. This system helps farmers strategically plan everything from feed requirements and livestock health monitoring to effective waste management. With an interconnected digital system, all farming activities become more transparent and easily monitored. This also improves management performance and enables decision-making based on valid and accurate data. Over time, the implementation of IoT can increase the competitiveness of the goat farming industry nationally and globally (Telkom University, 2025; Gonalves et al., 2024; Wong, 2025)

Strong policy development and support are essential to maintain the sustainability of this IoT system. Government policies that support investment in agricultural technology and regulations that guarantee data security are key factors. Furthermore, subsidies or incentives are needed for small and medium- sized farmers to enable them to access and utilize IoT technology. Synergy between the government, academia, the private sector, and livestock

communities must be strengthened to support education, training, and technology dissemination. Appropriate policies will encourage sustainable innovation and broader and more effective technology adoption (Mishra et al., 2023; Terence et al., 2024; Alfassa, 2025).

Technological innovation must also continue to focus on developing energy-efficient, durable, and easy- to-use hardware. For example, the use of solar panels as an alternative energy source can support the independent operation of IoT devices in remote areas without electricity. Developing an intuitive user interface and simple installation and maintenance processes significantly assist farmers in adopting this technology. Thus, technology becomes a tool that truly supports daily farming activities rather than an additional burden. Continuous innovation is the foundation for optimal long-term IoT functionality (Mishra et al., 2023; Telkom University, 2025). Jember State Polytechnic. (2024).

CONCLUSION

IoT development should focus on sensor accuracy and machine learning algorithms. The system must be designed to be modular and scalable for different farm sizes. A secure cloud computing platform is mandatory. Farmer training needs to be expanded for optimal technology use. Interdisciplinary collaboration should be strengthened, along with policies and regulations supporting sustainable IoT use.

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