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Smart poultry farming with IoT: an in-depth exploration of innovations and trends

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ABSTRACT

The internet of things (IoT) has emerged as a key enabling technology for smart applications such as smart homes, smart transportation, and smart agriculture. In traditional poultry farming, production largely depends on manual observation and human expertise, which often leads to inefficiencies and low productivity. IoT-based smart poultry farming provides automated monitoring and control of environmental parameters such as temperature, humidity, and poultry health using sensors and wireless communication technologies. This paper presents a comprehensive literature review of IoT-based smart poultry farming systems. This study systematically reviews 20 peer-reviewed studies published between 2013 and 2025, surveys existing IoT-based poultry farming solutions with a focus on sensing components, microcontroller platforms, system implementation approaches, and reported challenges in real-world deployments.

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1. INTRODUCTION

The rapid growth of the global population has intensified the demand for affordable and sustainable protein sources, making poultry farming a critical component of global food security. According to United Nations projections, the world population is expected to reach approximately 8.2 billion in 2025 and continue growing steadily in the coming [1]. Poultry meat and eggs remain among the most cost-effective sources of animal protein, driving increased pressure on poultry production systems. In developing countries such as Bangladesh, poultry farming also significantly contributes to employment generation and national economic growth. However, most farms still rely on manual monitoring and labor-intensive practices, limiting productivity, environmental control, and animal welfare. These challenges have accelerated the adoption of internet of things (IoT)-based smart poultry farming systems, which enable real-time monitoring, automation, and data-driven decision-making. In this context, IoT-based smart poultry farming is not merely a technological innovation it is an indispensable ICT infrastructure response to the challenge of ensuring global food security and employability [1]-[6].

Despite its economic significance (Bangladesh's poultry sector contributes 1.6% to GDP and supports nearly 6 million jobs [2]), poultry farming in Bangladesh predominantly relies on manual practices, including feeding, water management, waste removal, lighting control, and environmental monitoring. Most farms operate in simple mud or brick-built structures with open ventilation, requiring continuous human supervision

and substantial labor input. Such manual approaches often fail to maintain optimal environmental conditions, making 24/7 monitoring challenging and leading to inefficient farm management and reduced productivity. Existing IoT poultry farming systems use different sensors, devices, and communication methods, leading to interoperability challenges. Previous studies have not clearly identified this as the main barrier to large-scale deployment. To overcome these limitations, intelligent poultry farming has emerged through the integration of the IoT and related digital technologies.

Generic IoT-based smart poultry farming architectures typically incorporate a wireless sensor network (WSN) to collect real-time environmental data from the farm [7]. The data are transmitted via a gateway to cloud-based services for processing and analysis, after which control decisions are sent back to the farm controller to enable automated operations. Farmers can also remotely monitor farm conditions and adjust control parameters as needed. Smart poultry farming can be framed as an end-to-end ICT ecosystem integrating sensing, communication, edge/cloud computing, analytics, and automation whose practical viability depends on connectivity, interoperability, scalability, and reliable information exchange.

The primary contribution of this paper is to provide a comprehensive review of IoT-based smart poultry farming systems, covering data acquisition methods, sensor types, deployment strategies, different issues, and hardware platforms. Which also provides a technical reference for developing a scalable and interoperable systems. To achieve this goal, 20 research studies published between 2013 and 2025 are systematically reviewed and analyzed.

The remainder of this paper is organized as follows: Section 2 is the background studies on IoT and poultry farming. It describes some definitions and different key aspects of the relevant terms. Section 3 describes the research methodology and literature selection process, section 4 presents the key findings and discussion, and finally, section 5 concludes the paper with future research directions.

2. BACKGROUND STUDIES

The IoT, introduced by Kevin Ashton in 1999, refers to the integration of physical devices with computational systems through sensing, communication, and data processing technologies [8]. IoT enables real-time monitoring, automation, and intelligent decision-making, significantly reducing manual intervention across application domains. In agriculture, recent studies highlight the growing role of IoT combined with artificial intelligence in improving sensing accuracy, scalability, and decision support [3], [4].

In poultry farming, IoT technologies facilitate continuous monitoring of environmental parameters such as temperature, humidity, air quality, and lighting conditions. Automated control mechanisms improve productivity, optimize resource utilization, and enhance animal welfare. These capabilities form the foundation of modern smart poultry farming systems and motivate the systematic review presented in this paper.

3. STUDY METHODOLOGY

A structured literature review is adopted to systematically analyze IoT-based poultry farming as a multidisciplinary ICT domain, identifying architectural patterns, deployment constraints, and research gaps across sensing, communication, computing, and AI technologies.

3.1. Formulation of research questions

To systematically investigate the current research status of IoT-based smart poultry farming, six research questions (RQ1–RQ6) are formulated as follows,

QR1: What are the advantages and disadvantages of applying IoT technologies in poultry farming?

QR2: What is the generic system architecture and operational workflow of IoT-based smart poultry farming systems?

QR3: What key issues and challenges must be addressed in IoT-based smart poultry farming?

QR4: What types of IoT technologies are used in smart poultry farming systems?

QR5: Which sensors and hardware platforms are commonly used in IoT-based smart poultry farming?

QR6: What are the key system-level deployment challenges and future technological directions for IoT-based smart poultry farming systems?

The research questions follow an end-to-end ICT framework: RQ1–RQ3 address application benefits and challenges, RQ4–RQ5 identify underlying ICT technologies and sensing infrastructure, and RQ6 evaluates system-level requirements including scalability, latency, interoperability, reliability, and deployment readiness.

3.2. Searching and extracting information

The second stage of this study focuses on identifying and extracting relevant literature on IoT-based smart poultry farming using a structured search strategy. To ensure the inclusion of high-quality and credible studies, major digital libraries were systematically searched based on predefined keywords, publication period, and selection criteria, as summarized in Table 1. Geographical restrictions were not applied during the search process, rather, the studies were selected based on relevance to the research questions and methodological quality rather than country of origin. However, the final sample shows a notable concentration of studies from India, which likely reflects the volume of IoT-agriculture research output from that region rather than an intentional selection bias. Consequently, the technologies and architectures reviewed are broadly applicable, although the findings related to implementation cost and deployment scale should be interpreted with awareness of this regional concentration. Boolean search strings combining poultry farming and IoT terms (e.g., "smart poultry farming" AND "IoT" OR "WSN") were applied to 2013–2025 publications, with titles, abstracts, and full texts screened against inclusion criteria; duplicates and studies lacking technical IoT architecture details were excluded.

Table 1. Literature searching and information extraction strategy

Parameter	Description
Digital Libraries	IEEE Computer Society (IEEE CS), ScienceDirect
Search Engine	Google Scholar
Keywords Used	Smart Poultry Farming, Intelligent Farming, Poultry Monitoring System, Cloud in Poultry Farming, Internet of Things, IoT in Poultry, LoRaWAN
Publication Period	2013-2025
Geographical Focus	Global studies were considered without country-based restrictions. Although many selected studies were from India, inclusion was based only on relevance, methodological quality, technical contribution, and publication quality
Selection Criteria	Relevance to IoT-based poultry farming, clarity of methodology, and citation impact
Quality Assessment	Journal impact factor and publication credibility
Data Extraction Basis	Data were extracted using an ICT-oriented framework and mapped to RQ1–RQ6.
Research Question Mapping	Extracted data aligned with RQ1–RQ6

3.3. Screening and study selection

Relevant studies were identified by searching IEEE Computer Society, ScienceDirect, and Google Scholar using predefined keywords. Duplicate and irrelevant studies were removed through title, abstract, and full-text screening. The remaining articles were evaluated based on methodological quality, technical contribution, and relevance to the research questions (RQ1–RQ6). Finally, 20 studies published between 2013 and 2025 were selected for detailed analysis. Figure 1 illustrates the systematic framework used for selecting the relevant literature.

3.4. Quality assessment criteria and scoring framework

A structured quality assessment (QA) framework was applied to evaluate the reliability and methodological quality of all selected studies (presented in Table 2). Each study was assessed using six predefined QA criteria (QA1–QA6). A score of 1 was assigned if a criterion was satisfied; otherwise, 0 was assigned. The total quality score for each study ranged from 0 to 6.

QA1: Are the research objectives clearly stated?
QA2: Is the system architecture or framework adequately described?
QA3: Are the hardware, software, sensors, or communication components clearly presented?
QA4: Does the study provide implementation results, validation, or performance evaluation?
QA5: Is the study directly relevant to IoT-based smart poultry farming?
QA6: Was the study published in a recognized peer-reviewed journal or conference?

The overall quality score was calculated as,

$$\text{QA}_{\text{Score}} = \sum_{i=1}^{6} QA_i$$

where (QA_i) represents the score obtained for each assessment criterion. Most of the 20 selected studies achieved high quality, providing reliable evidence for analyzing IoT-based smart poultry farming.

Table 2. Comparative analysis and quality assessment of IoT-based smart poultry farming studies

Ref.	Venue (Rank)	Method	Technology	Main Contribution	Limitation	QA	Quality
[7] (2018)	IEEE IOTAIS (Conf.)	Prototype	IoT, WSN, Environmental Sensors	Real-time poultry environment monitoring	Limited field validation and scalability analysis	6/6	High
[8] (2019)	IEEE ICREST (Conf.)	Prototype	GSM, IoT, Arduino	Automated feeding and environmental control	GSM dependency and limited intelligence	6/6	High
[9] (2020)	Computers & Electronics in Agriculture (Q1)	Review	IoT, Smart Sensors, Big Data	Comprehensive overview of smart poultry management technologies	No practical implementation or performance evaluation	6/6	High
[10] (2018)	IEEE ICCIC (Conf.)	Prototype	IoT, Renewable Energy	Farm automation with integrated electricity generation	Small-scale experimental deployment	6/6	High
[11] (2020)	IEEE Comnetsat (Conf.)	Review	AI, IoT, Analytics	Review of AI-assisted poultry health monitoring	Lack of real-world validation	5/6	High
[12] (2019)	IEEE ICCET (Conf.)	Prototype	IoT, Wireless Sensors	Poultry house monitoring framework	Limited performance assessment	6/6	High
[13] (2016)	IJARCS (Q4)	WSN Prototype	IoT, WSN	Wireless monitoring of poultry farm conditions	No cloud integration or automation	5/6	High
[14] (2018)	Springer Conference	IoT Analytics	IoT, Image Processing	Disease detection using imagery analytics	Computational complexity and limited datasets	6/6	High
[15] (2014)	IJCA	Experimental	LED Control System	Smart lighting optimization for poultry growth	Focused only on lighting management	6/6	High
[16] (2022)	Webology (Q4)	Prototype	IoT, Cloud Monitoring	Efficient smart poultry monitoring system	Limited AI integration	6/6	High
[17] (2020)	Sensors (Q2)	Platform Design	IoT Platform, Cloud Computing	Enhancement of poultry production chain through IoT platform	High implementation cost	6/6	High
[18] (2013)	Journal of World's Poultry Research (Q4)	Review	Smart Sensors	Early discussion of smart sensing technologies in poultry farming	Conceptual with limited implementation evidence	5/6	High
[19] (2014)	IJSTR	Automation Study	IoT, Automation	Extension of automation technologies to farm environments	Limited poultry-specific validation	5/6	High
[20] (2017)	Conference	Prototype	IoT, Animal Health Sensors	Integrated animal health monitoring framework	Generic livestock focus rather than poultry-specific	4/6	Medium
[21] (2019)	IRJET	Prototype	IoT, Sensor Networks	Automated poultry monitoring and feeding system	Small-scale deployment	5/6	High
[22] (2016)	IEEE ICCSNT (Conf.)	Architecture Study	IoT, RESTful Services	Web-service-based livestock IoT architecture	Lack of implementation and performance evaluation	4/6	Medium
[23] (2020)	IEEE ICIEA (Conf.)	Case Study	IoT, Mobile Application	Smart poultry management for small farms	Limited scalability assessment	6/6	High
[24] (2015)	Indian Journal of Science & Technology (Q3/Q4)	Prototype	Internet-Based IoT	Internet-enabled smart poultry farm architecture	Limited automation functionality	5/6	High
[25] (2016)	Bonfring Journal	Prototype	Commodity Hardware, IoT	Low-cost smart poultry farming solution	Limited cloud and analytics support	6/6	High
[26] (2021)	Sustainability (Q1/Q2)	Predictive Model	IoT, Predictive Analytics, AI	Early disease prediction in poultry chickens	Requires large-scale real-world validation	6/6	High

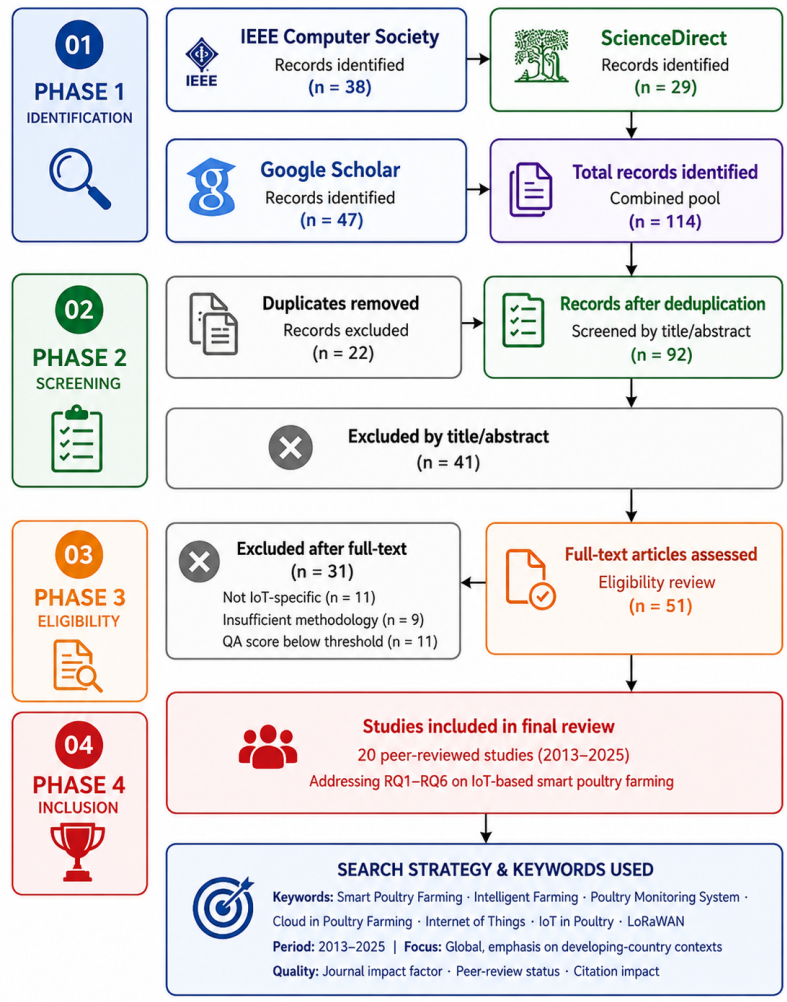

Figure 1. Framework for the selection of existing literature on IoT-based smart poultry farming

4. FINDINGS & DISCUSSION

This section addresses RQ1 to RQ6 by analyzing publication trends, commonly adopted IoT technologies, and architectural patterns in smart poultry farming systems.

4.1. Advantages and limitations of IoT-based smart poultry farming

Based on the analysis of the selected literature, Table 3 addresses RQ1 by summarizing the operational benefits and implementation challenges associated with IoT-based smart poultry farming systems.

Table 3. Advantages and limitations of IoT-based smart poultry farming

Advantages	Limitations
Automated and timely feeding and watering improve poultry health and growth [9], [10]	High initial cost for sensors, controllers, and communication infrastructure [5].
Automation enhances productivity and reduces human intervention [11], [12]	Requires skilled personnel for installation, operation, and maintenance [13].
Lower manpower requirement reduces long-term operational cost [6]	Continuous internet connectivity is essential for real-time monitoring [14]
Continuous gas monitoring and ventilation control maintain a healthy farm environment [15], [16]	Data processing and analysis may introduce latency in large-scale deployments [17]
Remote control of lighting, fans, and temperature improves environmental regulation [18], [19]	

The reviewed studies demonstrate that IoT technologies substantially improve farm productivity, environmental control, and operational efficiency through automation. However, high implementation costs, infrastructure requirements, and communication latency remain the primary barriers to widespread commercial adoption.

4.2. System architecture and operational workflow of IoT-based smart poultry farming

Figure 2 illustrates the generic system-level architecture adopted by IoT-based smart poultry farming systems ([5], [6], [9]-[17], [21]-[25]). Environmental and operational data are collected through sensors and processed by micro-controllers before being transmitted via communication networks and gateways to edge/cloud platforms. AI-based analytics process the collected data to support intelligent decision-making, while dashboards enable farmers to remotely monitor farm conditions and control farm operations.

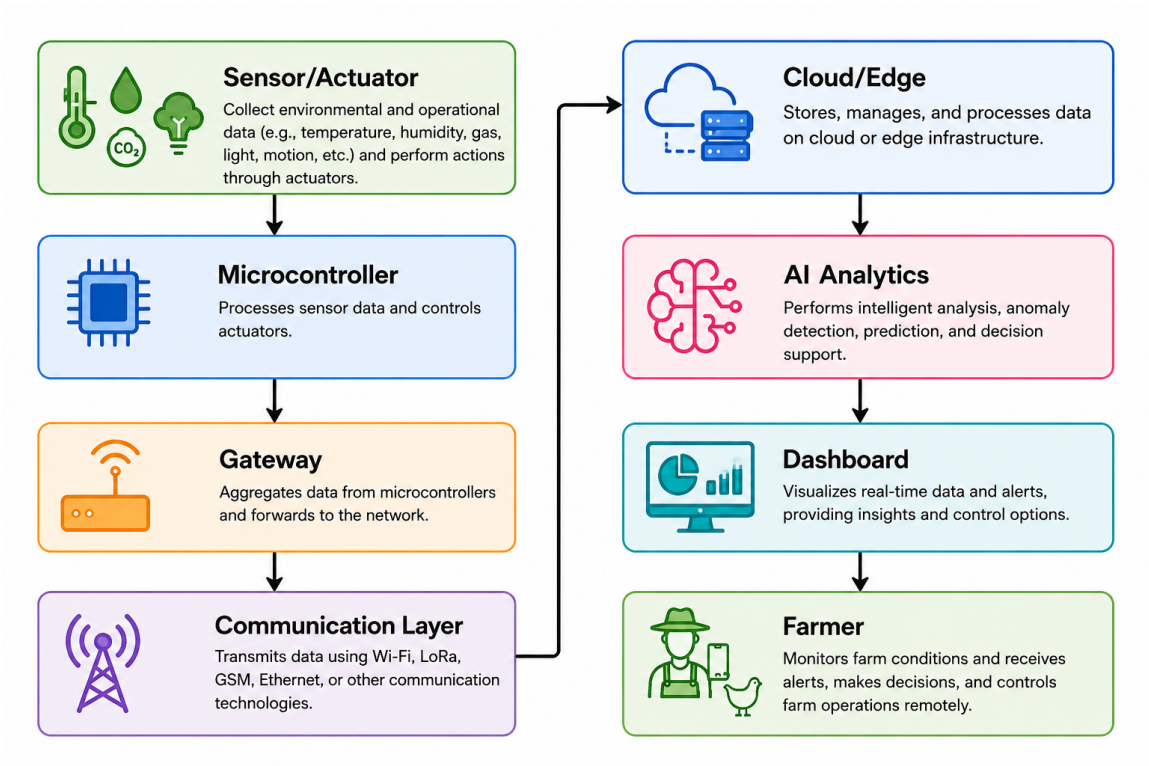

Figure 2. System-level architecture of IoT-enabled smart poultry farming systems (developed by the authors based on a synthesis of the reviewed literature ([5], [6], [9]-[17], [21]-[25]))

Figure 2 illustrates the ICT information flow from sensing to actionable decisions, showing how sensing, communication, gateway, edge/cloud, analytics, and application layers form an integrated system with bidirectional monitoring-control flow, while Table 4 summarizes the working approach of smart poultry farming systems.

Table 4. IoT-based working approach of smart poultry farming systems

Step	Process	Description
1	System deployment	Sensors, actuators, and controllers are installed to monitor farm conditions [9], [20]
2	Data sensing	Environmental and operational data such as temperature, humidity, and gas levels are sensed [14], [21]
3	Data aggregation	Collected data are processed locally or transmitted to cloud platforms [6], [17]
4	Data communication	Data are sent to gateways using wireless communication technologies [15], [16]
5	Intelligent decision-making	Rule-based or AI-driven analytics determine necessary control actions [5], [12]
6	Automated control	Actuators regulate feeding, ventilation, lighting, and gas removal [10], [19]
7	Remote monitoring	Farmers monitor and control farm operations via mobile or web interfaces [13], [18]

Despite differences in implementation, the reviewed systems consistently follow a layered architecture comprising sensing, edge/gateway processing, communication, cloud/edge computing, intelligent analytics, and application layers, indicating a common architectural paradigm for IoT-enabled smart poultry farming.

4.3. Issues in IoT-based smart poultry farming

Table 5 synthesizes the major operational and environmental challenges reported in IoT-based smart poultry farming literature, addressing RQ3.

Table 5. Different issues regarding smart poultry farming

Issues	Description
Lack of knowledge on smart technologies	Most farmers are unaware of the advantages of smart technologies in poultry farming [5], [6], [9]-[11], [13]-[26]
Feed and water related problem	Timely feeding and water supply are difficult to maintain manually in traditional poultry farming [5], [6], [9], [11]-[13], [15], [17]-[19], [21], [23], [26].
Disease and parasite related problem	Dust and unhygienic conditions in traditional farms increase the spread of diseases and parasites [5], [6], [9], [11], [12], [14], [17], [18], [20], [21], [24]-[26]
Temperature and humidity related problem	Temperature and humidity control is critical for poultry growth and survival [5], [6], [9]-[14], [16]-[21], [24], [25]
Light control related problem	Light exposure directly affects poultry growth, feeding behavior, and productivity [11], [13]-[15], [18], [19], [22], [23], [25].
CO_2, ammonia and oxygen related problem	Harmful gases produced in poultry farms negatively affect poultry health and the environment [5], [6], [9]-[12], [14]-[16], [25]

The analysis reveals that environmental control, disease prevention, and farmer awareness are the most frequently reported operational challenges, highlighting that successful IoT deployment requires both technological innovation and effective farm management practices.

4.4. Different types of IoT-based smart poultry farming

Based on sensing, automation, and decision-making capabilities, IoT-based smart poultry farming systems can be categorized into three major types, as summarized in Table 6. The evolution from internet-based monitoring to AI-enabled smart poultry farming reflects a clear technological progression toward intelligent, predictive, and autonomous farm management systems capable of supporting real-time decision-making.

Table 6. Different IoT-based smart poultry farming types

SL	Farming type	Key features and functionalities
1	Internet-based smart poultry farm	This system focuses on integrating wireless sensors and mobile network technologies to remotely monitor and control environmental parameters such as temperature, humidity, and ventilation inside the poultry farm. Real-time data access through the internet enables remote supervision and timely decision-making [9]
2	IoT-based smart poultry farm	An IoT-based smart poultry farming system automates core farm operations such as feeding, temperature regulation, gas removal, and water sprinkling using interconnected sensors and actuators. The system enhances farm efficiency by minimizing human intervention and enabling continuous monitoring of farm conditions [10]
3	AI-based smart poultry farm	This advanced system integrates IoT devices with artificial intelligence techniques to monitor poultry health and farm conditions. It employs sensors, video and image processing, bird behavior classification, and sound-based vocalization analysis to detect diseases, stress, and abnormal activities, thereby improving productivity, accuracy, and decision-making capabilities [5]

4.5. Sensor and boards are used in IoT-based smart poultry farming

The sensors and boards used in the reviewed papers have been identified and listed in Table 7 to address the fifth research question (RQ5). Figure 3 illustrates the sensing computing trade-off and the shift from basic IoT monitoring to intelligent, edge-enabled poultry systems.

The reviewed studies show that temperature, humidity, and gas sensors are most commonly used, with low-cost microcontroller boards dominating system implementation. Arduino UNO is the most widely adopted platform due to its simplicity and affordability [8], [16], [21], [23], [25], while Raspberry Pi is preferred for applications requiring higher processing capability and cloud integration [6], [9], [13], [25]. NodeMCU is used

in lightweight IoT deployments because of its built-in Wi-Fi support [27]. The limited use of vision and behavioral sensing indicates a gap in welfare-centric monitoring, which recent AI–IoT studies aim to address [28], [29]. However, the harsh poultry farm environment, characterized by ammonia exposure, dust accumulation, high humidity, and frequent temperature fluctuations, may adversely affect the long-term reliability of low-cost environmental sensors. Among the reviewed studies, the DHT11 was one of the most frequently adopted temperature and humidity sensors (Table 7), yet none of the reviewed papers reported long-term sensor drift evaluation, recalibration strategies, or maintenance protocols under practical farm conditions. Future IoT-based smart poultry farming systems should therefore incorporate periodic sensor calibration, redundant sensing, or more robust industrial-grade sensors to improve long-term monitoring reliability.

Table 7. Different sensors used in IoT-based smart poultry farming

SL	Sensor Name	Description
1	Temperature sensor	Measures environmental temperature. Examples include DHT11 and LM35 [5], [6], [9]-[14], [16]-[18], [20], [21], [24], [25]
2	Humidity sensor	Measures moisture content in the air and converts it into an electrical signal. Example: DHT11 [5], [6], [9]-[14], [16]-[21], [24], [25]
3	Gas sensor	Detects toxic and combustible gases such as ammonia and CO_2. Example: MQ-135 [5], [6], [9]-[12], [14], [16], [18], [25]
4	Ultrasonic sensor	Measures distance using ultrasonic sound waves. Example: HC-SR04 [11], [24]
5	IR sensor	Detects infrared radiation for motion or presence sensing. Example: RBD-0685 [11], [16], [19]
6	Dust sensor	Measures dust density in air using infrared light. Example: GP2Y1010AU0F [20]
7	Soil moisture sensor	Estimates volumetric water content. Examples include YL-69 and HL-69 [13], [20]
8	Fire detection sensor	Detects smoke and fire hazards. Example: AW-CSD381 [10], [19]
9	Door sensor	Detects opening or closing of poultry house doors [10]
10	Light sensor	Converts light intensity into electrical signals. Example: LM393 [11], [13]-[15], [18], [19], [22], [23], [25]

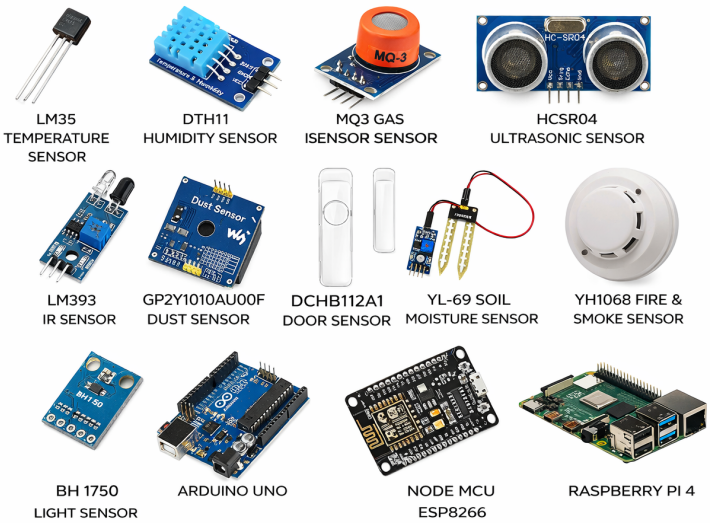

Figure 3. Sensors and boards used in IoT-based smart poultry farming

4.6. System-level deployment challenges and future technological directions

To address RQ6, Table 8 presents a comparative analysis of the system-level deployment characteristics reported in the reviewed studies.

The comparison examines four critical aspects of practical IoT deployment, namely scalability, communication latency, interoperability, and deployment trade-offs, together with their corresponding limitations, ICT impacts, and future research directions. This analysis extends beyond individual hardware or sensing technologies by providing a holistic system-level perspective on the challenges affecting the real-world implementation of IoT-based smart poultry farming. The reviewed studies indicate that most IoT-based smart poultry farming systems remain at the prototype or small-scale deployment stage. Although low-cost microcontrollers

and wireless sensors facilitate affordable implementation, limitations in scalability, interoperability, communication latency, and deployment cost continue to hinder large-scale adoption. Future systems should therefore adopt hybrid edge–cloud architectures and standardized communication protocols to improve reliability, responsiveness, and commercial viability. Furthermore, the limited real-world adoption of AI-enabled poultry farming systems is also constrained by the high computational requirements of deep learning models, the need for large, well-annotated datasets for reliable model training, and the limited availability of edge computing resources in commercial poultry farms.

Table 8. Comparative analysis of system-level deployment in IoT-based smart poultry farming

Sl. No.	Aspect	Current Practice	Limitation	ICT Impact	Future Direction	Ref.
1	Scalability	Small-scale IoT deployment	Limited large-scale validation	Reduces commercial adoption	Edge-enabled scalable systems	[5, 17, 28, 29]
2	Latency	Cloud-based monitoring	Communication delay	Slower real-time response	Hybrid edge–cloud processing	[14, 16, 17, 26]
3	Interoperability	Heterogeneous devices	Protocol incompatibility	Limits system integration	Standardized IoT protocols	[9, 17, 22, 23]
4	Deployment	Low-cost IoT platforms	Cost–performance trade-off	Affects reliability	Adaptive IoT architectures	[5, 16, 25]

Findings reveal a prototype-to-maturity gap: sensing and automation are established, but communication reliability, interoperability, scalable computing, and standardized evaluation remain underaddressed. Smart poultry farming constitutes an end-to-end cyber-physical ICT system dependent on coordinated sensing, communication, computing, analytics, interoperability, automation, and applications [5], [16], [17], where ICT advances dictate scalability, responsiveness, reliability, and intelligence.

Overall, this review provides a structured technical reference by synthesizing the advantages, system architectures, enabling technologies, deployment challenges, and hardware platforms of IoT-based smart poultry farming into a unified analytical framework. The findings can guide researchers, system developers, and policymakers in designing interoperable, scalable, and AI-enabled poultry farming systems for large-scale deployment. However, this review is limited to 20 peer-reviewed studies published between 2013 and 2025 and does not consider commercial IoT platforms, patents, or unpublished industrial implementations. In addition, variations in experimental settings, evaluation metrics, and deployment scales across the reviewed studies preclude direct quantitative comparison of system performance.

5. CONCLUSION

This study systematically reviews 20 peer-reviewed studies on IoT-based smart poultry farming published between 2013 and 2025, synthesizing key technologies, sensors, hardware platforms, system architectures, and deployment challenges. The findings show that smart poultry farming is evolving from sensor-based monitoring toward an integrated ICT ecosystem combining wireless sensing, communication networks, edge/cloud computing, AI-driven analytics, automated control, and remote farm-management applications. However, scalability, interoperability, communication latency, connectivity, computing requirements, and implementation cost remain major barriers to large-scale deployment. Future work should establish ICT benchmarks for reliability, latency, interoperability, security, energy efficiency, and scalability enabling cloud-based management, AI-assisted detection, and data-driven decisions to position IoT poultry farming within scalable smart agriculture and food-security strategies. Institutional and government support will also be important for translating these technological advances into sustainable real-world deployment and socio-economic benefits.

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AUTHOR CONTRIBUTIONS STATEMENT (MANDATORY)

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal Analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject Administration
Fu : **Fu**nding Acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest regarding the publication of this paper.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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