AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 03, Issue: 06 (June, 2026)
Available online at http://www.agrimagazine.in
©Agri Magazine, ISSN: 3048-8656

Revolutionizing Food Production and Quality Control by Internet of Things (IoT)

*Priyanka Bharti
PhD. Scholar, Dept. of Processing and Food Engineering, College of Engineering and Technology, OUAT, Bhubaneswar, India
*Corresponding Author's email: priyankabharti.rs22@ouat.ac.in

The Internet of Things (IoT) is changing the way foods are produced and monitored, with IoT there can be real-time monitoring of food production processes from agriculture to processing and logistics through smart sensors and data analytics and the use of blockchain technology. Although IoT faces problems such as expensive initial costs and regular sensor maintenance, its future holds smart packaging and predictive AI applications.

Introduction

Global food supply chains are under severe strain. According to recent studies by the United Nations Environment Programme (UNEP) and Food and Agriculture Organization (FAO), about 1.05 billion tons of food are wasted each year, which amounts to 19% of total available food. The cost associated with this is about one trillion USD every year. Most importantly, 13% of the food is wasted in the early stages of the food supply chain from production to harvest and initial transportation, even before it reaches the shelves of retailers or kitchens of consumers. To sustainably feed the increasing population globally amid huge economic and environmental wastage, there is an ongoing technological revolution in the food sector. The key to this change is the Internet of Things (IoT). Moving beyond conventional reactive methods that depend on manual sample collection and post-process laboratory testing, IoT presents a more forward-looking solution. This technology establishes a network of intelligent devices including sensors, actuators, and communication units that can gather, transmit, and analyse data in real-time throughout the entire process of agriculture and food production. Transforming physical measurements (e.g., ambient temperature, humidity levels, and chemical markers) into digital data, IoT enables participants to gain access to a high level of transparency, quality assurance, and efficiency of resources (Aamer *et al*. 2025).

The Architectural Core of IoT in Food Systems

In order to comprehend how IoT functions in food production, one should regard it as a structural architecture with various levels. This type of architecture changes gradually from physical equipment to cloud-based predictive intelligence. The conventional architecture is usually characterized by three main layers, which include:

- **The Perception Layer (Smart Food Sensing)**

Hardware is the most fundamental element that constitutes an IoT ecosystem. When we consider the hardware component of a food system ecosystem, this would include edge devices, RFID tags, WSNs, and biosensors. The use of these elements goes beyond the mere identification of the product; rather, they will serve as a monitoring tool for the micro environment in which the products are kept. For example, new biosensors make use of the biological recognition element such as enzymes and antibodies combined with transducers to detect the smallest biochemical change and translate it into electrical energy (Sebti *et al*. 2026).

- **The Network and Communication Layer**

The data captured through edge sensors has to be conveyed effectively to the processing unit at the centre. Such a layer depends on diverse communication protocols to meet the logistics needs:

- ✓ Suitable short-range communications include Bluetooth low energy (BLE) and Near field Communication (NFC) used for localized scanning of inventories.
- ✓ Suitable long-range communications involve Low power wide area network (LPWAN) such as LoRaWAN that is best for expansive agricultural land areas, and cellular networks that come with GPS modules for tracking cross-country fleets.

- **The Application and Data Analytics Layer**

In the higher levels, cloud computing platforms and computation nodes (such as microcontrollers used in edge computing like the Raspberry Pi devices) handle the processing of the data streams coming in. In these stages, the parameters are compared to baseline food safety models using machine learning and AI technology. In case there is any deviation, for instance, a sudden increase in temperature in the cargo truck, an alert is raised (Babu *et al*. 2023).

Critical Parameters Tracked by IoT Sensing Networks

Food safety and quality degradation largely depend on the environment (Table 1). Proper selection of the right sensor array is crucial for the prevention of spoilage and compliance with the stringent food laws globally.

Table 1. Critical Environmental Parameters Monitored by IoT Sensors in Food Systems

Parameters	Sensing technology	Impacts on food	Food deterioration
Temperature	Thermistors, RTDs, Infrared Sensors	Dairy, Meat, Seafood, Frozen Goods	Pathogen proliferation (e.g., *Salmonella*), enzyme degradation, and rapid melting.
Relative Humidity	Capacitive and Resistive Humidity Sensors	Grains, Fresh Produce, Baked Goods	Moisture loss causing wilting, or high humidity driving Mold and fungal growth.
Gas Concentration (CO_2, Ethylene)	Electrochemical and NDIR Gas Sensors	Fruits, Vegetables, Controlled-Atmosphere Silos	Accelerated ripening (driven by ethylene) and anaerobic fermentation.
Volatile Organic Compounds (VOCs)	Metal-Oxide Semiconductor (MOS) Sensors	Fresh Seafood, Poultry, Meats	Release of volatile amines and sulphur compounds indicating microbial spoilage.
Location & Light Exposure	GPS Modules, Photodiode Light Sensors	High-Value Crates, Cold-Chain Logistics	Photo-oxidation of fats/oils, unexpected cargo tampering, and route tracking.

Streamlining Food Production: Smart Agriculture and Processing

IoT implementation results in optimizing the processes using big data and technology throughout the process of agricultural production and food processing industries.

- **Precision Farming and Yield Optimization**

In production, IoT makes sure that there is no waste of resources in the form of precise farming (Figure 1). The sensors planted in the soil to measure the moisture levels and pH levels can directly connect to the automation of irrigation systems. At the same time, weather monitoring facilities forecast local frosts and droughts, allowing the farmers to take preventive measures. Regarding animal husbandry, IoT collar tags and ear tags monitor the movement patterns, body temperatures, and other biometric data. It allows detecting disease outbreaks and automated management of herds, thus preventing the overuse of prophylactic antibiotics.

- **Industrial Food Processing and Automation**

Once the ingredients are inside the processing factory, the automated processing equipment uses IoT to achieve quality control standards. Constant thermal sensors monitor pasteurization and sterilization processes, ensuring that the thermal death point of any pathogenic bacteria is reached without overcooking and compromising nutrient content (Figure 1). Moreover, vibration and acoustic sensors placed on the mixing machines, sorting machines, and ovens function as predictive maintenance tools. The sensors alert about machine anomalies before the machine malfunctions, thereby preventing processing plants from experiencing costly unscheduled downtime leading to spoilage of whole batches of raw, perishable food within the factory premises.

Figure 1. Smart agriculture and food processing by IoT

- **Elevating Quality Control: Intelligent Distribution and Cold-Chain Logistics**

The transportation process from the processing centre to the retail store is one of the vulnerable stages in the preservation of foods. For perishables, the maintenance of the cold chain, which is a temperature-controlled environment in the logistics process, is crucial for their preservation (Figure 2). For years, the conventional cold chain monitoring involved the use of passive data loggers to measure the internal temperatures in the course of transport (Kaur *et al*. 2022). However, this technology was only reviewed upon arrival at the point of destination. The problem with this technology is that if there was an interruption in the cooling process during a three-day transport process, the products were disposed of immediately due to spoilage. The IoT has changed this scenario to one that involves telemetry through real-time monitoring and control.

- **The Real-World Impact: Enhancing Traceability and Reducing Waste**

An extensive review of digital technologies within sustainable food supply chain systems emphasizes the structural advantages of this timely shift. As seen through numerous studies on supply chains, the inclusion of IoT technology provided 83% positive effect in reducing food waste and an 89% positive effect in the stringent verification of food safety indicators.

These constant data flows are enhanced by digital ledger systems such as the blockchain, which form an unalterable and transparent timeline of the product's journey (Table 2). In the event that a pallet of fruits has experienced an unanticipated temperature change, shipping coordinators are alerted to the problem and can redirect the shipment to a nearby store for immediate sales, thus preventing the loss of the entire shipment.

Table 2. Distribution of Digital Technologies in Modern Agri-Food Supply Chains

Technologies	Distribution %	Focus area	Contributions
Blockchain	41.3%	End-to-End Supply Chain	Providing unalterable data transparency, anti-counterfeiting tracking, and verified origin proofs.
Internet of Things (IoT)	26.1%	Storage, Transportation, & Logistics	Real-time environmental parameter capturing, alert generation, and cold-chain monitoring.

AI & Machine Learning	19.6%	Processing & Predictive Maintenance	Predicting remaining product shelf-life, optimizing transport routing, and automated sorting.

Challenges

Though effective in terms of outcomes, implementation of IoT technologies into global food systems encounters some challenges from a technological standpoint:

- **Large Initial Investment**: The deployment of a robust system of sensors and other IoT components within the massive area of agricultural lands, along processing lines and delivery vehicles is associated with a significant amount of capital expenses. This makes the technology unaffordable for small and medium-sized businesses, as well as smallholders.
- **Lifespan of the Sensors, Their Accuracy and Maintenance Needs:** Food manufacturing facilities operate in conditions of extreme temperatures, humidity, chemical treatments and disruptions. Thus, it is necessary that sensors do not degrade their performance over time, while some biochemical and gas sensors need regular calibration and tend to get worn out quickly.
- **Data Security and Interoperability of Systems:** Since the current food chains have different and independent players like growers, third-party logistics firms, processing units, and global retailers, their systems operate through disjointed software programs. The lack of uniform data formats may lead to interoperability issues. Moreover, securing data against any external cyber-attacks is always essential.

Future prospects

The future of Internet of Things technology in the food industry lies in more advanced integration, miniaturization, and smart packaging solutions.

The following recent trends indicate a very sophisticated automated and self-sufficient network of supply chain:

- **Smart Active Packaging**

The boundaries between the product packaging and digital sensors become blurred. Scientists are working on development of biodegradable and edible packaging films which include micro-biosensors, and thus can be embedded directly into the consumer packaging (Li et al. 2026). In contrast to the traditional printed label "Best Before", this kind of packaging monitors the chemical reactions in the packaging itself in real time, for example, the formation of volatile amines when meat ages.

- **Deep Integration with AI and Distributed Ledgers**

IoT systems, as they continue to scale up, will produce huge amounts of data every day. Future food systems will increasingly take advantage of such data alongside advanced AI systems for dynamic prediction of shelf-life of products, depending on the actual environmental conditions during transportation, with the help of IoT data being fed directly into smart contracts via blockchain technology, business transactions can be completed effortlessly (Sebti et al. 2026). In the case where an IoT system confirms that an incoming shipment of seafood had been transported under optimum temperature conditions, a smart contract could pay the seller immediately on arrival. If a deviation from such temperatures is noted, then other measures could be taken accordingly.

Conclusion

Integrating the Internet of Things into food production and quality assurance represents a drastic move from a more reactive approach to food management in favour of a proactive one. The ability of the Internet of Things to ensure continuous monitoring of soil health, manufacturing, and transport environment helps to secure food safety and minimize food waste around the globe. Despite some financial and technological barriers that are still to be overcome, the progress in the field of sensor longevity, use of AI, and intelligent packaging keeps making these barriers smaller. For scholars, practitioners, and policymakers, development of such interconnected systems is not just a technical need; it is an indispensable step for securing a robust and sustainable food supply chain around the globe.

Figure 2. Use of IoT in different agricultural sectors

References

1. Aamer, A. M., Al-Awlaqi, M. A., & Rausyan Fikri, M. (2025). Smart food logistics: design and test of an IoT-based food traceability system. *International Journal of Logistics Research and Applications*, 1-20. https://doi.org/10.1080/13675567.2025.2531796
2. Babu, K., Suthar, M. B., Ramesh, S., Saketh, P., & Thakur, A. (2023). Next-Generation Food Safety Monitoring Using Biosensors and Internet-of-Things Technologies. *Journal of Food and Biotechnology*, *4*(2), 11-20. https://doi.org/10.51470/FAB.2023.4.2.11
3. Kaur, A., Singh, G., Kukreja, V., Sharma, S., Singh, S., & Yoon, B. (2022). Adaptation of IoT with blockchain in Food Supply Chain Management: An analysis-based review in development, benefits and potential applications. Sensors, 22(21), 8174. https://doi.org/10.3390/s22218174
4. Li, S., Li, H., & Kong, T. (2026). Digital technologies for sustainable food supply chains: a scoping review of impacts on food safety, loss reduction, and implications for nutritional security. Frontiers in Nutrition, 13, 1796752. https://doi.org/10.3389/fnut.2026.1796752
5. Sebti, M. R., McCarthy, U., Ktenioudaki, A., Russo, M., & Merenda, M. (2026). Traceability and anti-counterfeiting in agri-food supply chains: A review of RFID, IoT, blockchain, and AI technologies. Sensors, 26(5), 1685. https://doi.org/10.3390/s26051685