# Prospects of IoT Technology for Supply Chain Traceability of GI - Tagged Nendran Bananas in Kerala: A Review

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Keywords: Internet of Things (IoT), Radio Frequency Identification (RFID) Tags, QR Codes, Supply Chain, Traceability, Bananas, Nendran, Geographical Indication.

Abstract: Nendran bananas are the exclusive commercial plantain variety of Kerala due to a combination of climatic conditions, traditional farming practices, geographical indication recognition, culinary importance, export demand, and cultural significance. However, the fragmented supply chain, together with the absence of quality certification and traceability, adversely affects worldwide demand, market linkages, and finance of the engaged stakeholders. The potential application of Internet of Things (IoT) technology to the supply chain management of Kerala's Nendran bananas is examined in this review study. The Internet of Things (IoT) allows for seamless data sharing, which enhances productivity, efficiency, automation, and decision-making. IoT sensors, found on the farm and in consignments, provide the banana industry with actionable insights that increase farm productivity, lower the cost of essential inputs, and improve post-harvest yield and quality. Besides solar-powered inline nitrate sensors that monitor sediment, control irrigation levels, and limit fertilization usage, onsite IoT sensors also serve as weather monitoring stations and prevent nitrate runoff. These sensors make it possible to gauge the fruit's size and comprehend the influence of the weather on the yield. Bunches of bananas with radio frequency identification (RFID) tags track their upkeep, harvesting, sorting, and transportation while cutting expenses and lowering environmental impact. RFID readers that use ultra-high-frequency technology track the products' movements and by scanning QR codes, consumers can monitor the route of the banana directly from its origin. These real-time views of the farm or supply chain, provide data to validate that each banana was produced in high environmental standards. Consumer confidence is increased by transparency and traceability from the farm to the plate, and data can guarantee the integrity of food safety. Kerala government must implement supply chain traceability by incorporating IoT technology into export-oriented horticultural products, like Nendran bananas, to achieve notable improvements in productivity, precision, and sustainability.

## 1 INTRODCUTION

Bananas are one of the most nutritious, popular, and economically important horticultural products of Kerala. Nendran bananas, especially the Chengalikodan banana variety from Thrissur district, are exclusive commercial plantain varieties of Kerala due to their geographical indication recognition, culinary importance, export demand, and cultural significance. Hence high demand is observed for Nendran bananas in domestic and overseas markets wherever the Asian diaspora is settled. However, the fragmented supply chain of Nendran bananas has a lot of challenges that adversely affect quality standards, market linkages, and financial aspects of all involved stakeholders. Utilizing cutting-edge technologies like the Internet of Things (IoT) and sophisticated sensors could increase agricultural output and reduce financial loss. Numerous global studies have adequately shown how integrated IoT-smart sensors may be used to monitor environmental parameters, including temperature, humidity, moisture content, and soil composition, that are essential for crop growth. With the advent of the Internet of Things, agricultural supply chain traceability should be built to provide assurance. Global tracking and automatic product identification for agricultural products offer comprehensive data covering the whole product life cycle. Hence, by employing IoT to optimize the supply chain that links farmers and their products, transparency is preserved.



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### 1.1 Research Questions

This review paper addresses the following research questions.

- How authenticity, quality and product provenance can be ensured in GI-tagged fruits of high demand like Nendran banana?
- How Internet of Things (IoT) technology can address these issues, provide supply chain traceability and ensure the reputation of Nendran banana for quality?

### 1.2 Objectives

The objectives of this review paper included;

1) Examining prospects of application of Internet of Things (IoT) technology in production and supply chain traceability and management of fresh farm produce including banana.
2) Reviewing the role of IoT sensors, Radio Frequency Identification (RFID) tags and Quick Response (QR) codes in supply chain traceability of fresh farm produce including GI-tagged Nendran bananas.

## 2 METHODOLOGY

This review paper utilized a systematic literature review (SLR) following the below review protocol. Databases viz. sciencedirect.com, nih.gov, nature.com, springer.com, elsevier.com and research papers in other open-access peer-reviewed journals were looked upon with a specific focus on reviewing the published research work to attain an unbiased and objective summary of the current state and future potential of IoT applications in production and supply chain traceability of fruits like banana. SLR evaluates and interprets all existing research pertinent to a question, issue, or phenomenon of interest using a scientific and replicable methodology (Cook *et al.,* 1997; Booth *et al.,* 2012).

Other than the relevant keywords, the searched items included, in particular, the employability of IoT sensors, RFID tags and QR codes in the production and supply chain of fresh farm products in different parts of the world for which the search strings were established using Boolean logic, with OR/AND. The latest and relevant results and salient findings were summarised and presented year-wise.

## 3 RESULTS AND SALIENT FINDINGS

### 3.1 IoT Sensors

With the use of several low-cost sensor nodes, the Internet of Things (IoT) is rapidly expanding its use in agricultural modernization. It can track crop disease and insect incidence from a micro level and gather real-time weather data related to crop growth. Enhancing agricultural productivity and reducing financial loss could be achieved by integrating cutting-edge technology like the Internet of Things (IoT) with sophisticated sensors. Many studies around the world have satisfactorily shown how integrated IoT-smart sensors can be used to monitor environmental factors that are essential to crop growth, such as moisture, temperature, humidity, pollution, water content, soil quality, radiation, and soil composition. Sensors that are automated are also used to measure greenhouse gasses like carbon dioxide, methane, etc. Additionally, smart farming makes it possible to measure the quantity of nitrogen in the soil, which aids farmers in figuring out how much fertilizer to apply to their fields. Furthermore, smart farming enhances precision through improved agricultural work management and timely decision-making based on collected data (Rajak *et al*., 2023). Farmers may better manage their crops and vegetables over a wider area in less time by combining the Internet of Things with a variety of smart sensors. IoT may also make it easier to determine when and why to apply fertilizer and pesticides in the field. IoT applications might undoubtedly cut down on resource waste while safeguarding farmers' profits. IoT sensors provide the banana industry with actionable insights that increase farm productivity, lower the cost of essential inputs, and improve post-harvest yield and quality. These sensors can be found on the farm and in consignments that are delivered to customers. In addition to solar-powered inline nitrate sensors that monitor sediment, control irrigation levels, and limit fertilization usage, onsite IoT sensors also serve as weather monitoring stations and prevent nitrate runoff. These sensors make it possible to measure the fruit size and comprehend how the weather may affect harvests in the future. Food quality assurance (such as testing for contaminants, toxins, and packaging) and plant development monitoring (such as phenotyping, stressors, volatile organic components, nutritional levels, hormones, and pathogens) are two areas where sensors are useful.

In 2023, Ataei *et al.* recognised the use of IoT-enabled sensor technology to measure current emperature, soil moisture, humidity, and water usage for fieldwork. It also analyzes decisions made in conjunction with farmers, automates water and fertilizer delivery, and regulates system temperature, relative humidity, oxygen and carbon dioxide levels, vibration, and shocks. Understanding these factors is beneficial for optimizing the quality of the final product, as stated by Keates (2023), Lamberty and Kreyenschmidt (2022), and Sekaran *et al*. (2020).

***Water management with IoT sensors:*** Lakshmi *et al.* (2023) accurately calculated the amount of water required for tomato and eggplant crops by utilizing sensors and Internet of Things scheduling. When the irrigation was managed with these soil moisture sensors, the plants looked better and needed 46% less water.

***IoT devices for monitoring pests and diseases:*** According to Nandhini *et al.* (2022), IoT sensors were shown to be beneficial in the Compressive Sensing Integrated Disease Detection System for the aim of monitoring banana plant diseases, such as bunchy top and sigatoka leaf spot. Colour and temperature sensors were employed by Duraianand and Sivasangari (2022) to detect leaf diseases in bananas, such as Sigatoka and black leaf streak. An IOT sensor network and machine learning techniques were successfully used by Silupu *et al*. (2021) to predict the incidence of thrips in organic bananas.

***IoT sensors for managing fertilizer and soil:*** Grand Nain Bananas used less water and NPK fertilizer as a result of IoT sensors for IoT-based soil water potential sensors, which decreased financial risk for farmers (Salimath *et al.,* 2023). According to Fan *et al.* (2022), an IoT system for real-time soil monitoring could reveal the paths through which nitrogen is lost during the production of bananas, as well as weather data, soil moisture content, and surface water runoff. In bananas, an Internet of Things machine learning model can determine whether the soil condition is ideal, adequate, or unacceptable (Iorliam, 2022). Real-time soil nitrate concentration monitoring—an IoT node with ion-selective electrode soil nitrate sensors for precision agriculture—can help with decisions about fertilizer management, increase the efficiency of N use, and decrease nitrogen losses to the environment. (Bristow *et al.,* 2022)

***IoT sensors for harvesting and ripening:*** According to Altaf *et al*. (2020), wireless sensor networks (WSN) and Internet of Things (IoT)-based neural networks were utilized to remotely monitor the ripening of bananas in Pakistan. The use of AI in banana production aids in the detection of crop type, crop grade, ripeness, leaf diseases, and soil control. (Almeyda and Ipanaqué, 2022).

***IoT sensors in polyhouse:***

For Nepali smallholder farmers to display, monitor, and control real-time data about their crops, livestock, and other agricultural assets Lamsal *et al*. (2023) created an affordable, configurable, scalable, and reliable Internet of Things platform. Eighty-four percent of the citrus plants grafted during the offseason were successful thanks to the platform, which was set up within a polyhouse.

## 3.2 RFID Tags

IoT solutions based on radio frequency identification (RFID), such as RFID tags on banana bunches, monitor the care, harvesting, sorting, and shipping of the bananas, increasing productivity while cutting costs and decreasing environmental impact. While handheld scanners read the ultra-high frequency RFID tags, they send the data to the cloud. Fruit and vegetable boxes with RFID tags use RFID readers that track the products' movements as they go from fields to distribution centres and then to retail locations.

These devices keep an eye on the farm's or supply chain's circumstances in real-time and provide recommendations based on the software they access and monitor. To sell fruit as a premium product rather than at a discount, the producer can simply track any tainted batch of food back to its source by removing the information from an RFID tag. From the farm to the market to the customer, the information on the tags verifies that every banana was grown under strict environmental guidelines. Data can ensure the integrity of food safety, and transparency and traceability from the plantation to the plate can increase consumer confidence.

Mango farms use RFID-Based Fruit Monitoring and Orchard Management Systems, where each employee is given a duty list that includes spraying, plucking, and early fruit cover with bags. The status is updated in the cloud database once the tasks are completed. (Imdaad *et al.*, 2023). Humidity, temperature, gas, pH, integrity, and traceability sensors for food packaging are identified by RFID-based sensing in smart packaging (Zuo *et al.,* 2022).

According to Nugraheni *et al.* (2016), RFID technology was utilized in Indonesian banana traceability systems so that customers could view details about the product, including planting and harvesting information.

According to studies by Kavya (2012) and Verma *et al*. (2015), colour indices of bananas can be used

by RFID technology to track the ripening process of bananas. With its focus on expiration dates and remaining shelf life, RFID could be advantageous to distributors, retailers, and consumers in the supply chain of extremely perishable food. (Grunow and Pira, 2013).

RFID-based technologies have the potential to produce automated alerts for containers that have lower banana green life or temperature issues. They can also remotely monitor the ripening process within the container. Controlling waste and losses, recycling, identifying undesired ripening and volatile components that suggest mold infections, and monitoring and controlling the food quality evolution during its postharvest life are just a few of the environmental problems they could take on. Batch mixing incidents might be found, and compromised batches could be removed from the market and supply chain. Negara and Dachyar (2021), Navarro *et al*. (2021), Onwude *et al*. (2016), Duroc and Kaddour (2012) and Jedermann *et al.* (2006).

### 3.3 QR Codes

QR codes are utilized to provide nutritional information about products and to provide transparency in the banana supply chain (Hassoun *et al.,* 2023; Surbhi Bhatia and Albarrak, 2023). According to Kavyasree and Natarajan's (2022) research, QR codes utilizing laser technology in exotic dragon fruit provide a sustainable, anti-counterfeiting, hygienic, clean, and non-contact traceability solution. QR codes also provide traceability from production to customer. In addition to increasing transparency, lowering the cost of food recalls, and reducing waste and loss, it also improved the safety and quality of numerous fruits and vegetables. Recently, the Vegetable and Fruit Promotion Council Keralam (VFPCK), in Kerala, employed QR codes to boost banana exports and fetch better prices by leveraging geographical indications, ensuring the Nendran Banana's reputation for quality. This can be replicated in the case of other fresh produce with export potential.

## 4 CONCLUSION AND SUGGESTIONS FOR SUPPLY CHAIN MANAGEMENT OF GI TAGGED NENDRAN BANANA

Since fresh food has historically not been particularly sensitive to margins, losses from spoiling have been accepted as a necessary expense of conducting business. Gathering data is crucial to understanding how a firm operates, particularly in the fresh food industry. To provide clear and reliable insight into the efficacy and inefficiencies along the supply chain, it is imperative to capture the appropriate data. Cost-effective IoT sensor integration into processes facilitates information gathering, accurate company health assessment, and necessary correction before a poorly thought-out or inadequate decision ruins business outcomes.

Knowing about problems as they arise helps ensure that none of the problems affecting the farm produce's remaining freshness turn into real problems. Product management from field to shelf affects how fresh it remains. When paired with cloud-based predictive analytics, IoT technologies keep an eye on a wide range of characteristics and may precisely estimate a product's remaining freshness and offer an up-to-date snapshot of its handling. This makes it possible for supply chain managers to proactively manage farm output using actual product data as opposed to the present simpler assumptions based on harvest date (which presumes uniform processing) or visual inspection. IoT technology adoption can have a significant impact since it is far better at providing the kind of data and knowledge required to guide proactive decision-making and correct inefficiencies. Growers can increase the profitability of the food they labour so hard to produce, merchants can provide their customers with a high-quality product, and consumers may feel more confident about their purchases by proactively managing the products through the supply chain.

By enhancing decision-making at every stage and hence lowering food waste, IoT technology and cloud-based analytics have the potential to change the fresh food supply chain completely. Internet of Things (IoT) sensors can change an assumption-based supply chain into one driven by real-time, detailed data showing how to make the best decisions possible. Growers, processors, distributors, and retailers can optimize food waste and increase food safety and supply chain transparency by implementing a data-driven approach that leverages IoT and cloud analytics to solve the hidden issues affecting the fresh food supply chain.

Based on the research findings, it is evident that IoT is poised to bring about remarkable transformations in the production and supply chain of GI-tagged farm produce like Nendran bananas with the potential for enhancing efficiency, accuracy, and sustainability in production and profits. As the preliminary step, farm/farmer profiling is to be

carried out by assessing the landholding information under Nendran bananas. Geo-mapping of Nendran banana farms can be done by connecting each harvest to geo coordinates and unique QR codes. IoT sensors can be employed on farms to follow a package of practice recommendations from planting to harvest stage. RFID tags can enhance the sales margin by assessing the optimal period of harvest and leading to sales of products as per market demands. Quality adherence to post-harvest processes and traceability in transportation to know the origin, grade, supply chain touch points, and feedback provision are possible by the use of IoT sensors, RFID tags, and QR codes in banana production and export for ensuring overall quality supply chain and export of GI banana. Consumer confidence is increased by transparency and traceability from the farm to the plate, and IoT data can guarantee the integrity of food safety. Kerala must implement supply chain traceability by incorporating IoT technology into export-oriented horticultural products, like Nendran bananas, to achieve notable improvements in productivity, precision, and sustainability.

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