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Internet of Things (IOT): The Future of Food Safety and Supply Chain Traceability

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SUMMARY

IoT technology is revolutionizing food safety practices by enabling traceability, safety monitoring, and supply chain transparency. It allows stakeholders to monitor food conditions in real-time, reducing risks of contamination and minimizing wastage. Key benefits include improved food safety through real-time monitoring, accurate predictions of risks like disease outbreaks, reduced food wastage through expiry date tracking, enhanced supply chain transparency, optimized logistics, and automated compliance reporting. IoT applications cover complex and geographically extensive food supply chains, addressing challenges posed by population growth and offering comprehensive functionality across all stages of food production and distribution. Overall, IoT integration in food safety represents a transformative shift, enhancing efficiency, quality, and sustainability in the food industry.

INTRODUCTION

"IoT technology helps with improving food safety. In the food industry, it enables the tracking of food products from farm to table, so you can have detailed information about the food." The Internet of Things (IoT) connects devices with sensors and software, enabling them to exchange data over the internet. These devices range from simple sensors to complex systems that can be monitored and controlled remotely. Key components include sensors, actuators, embedded systems, and wireless communication technologies like Wi-Fi and Bluetooth. As IoT evolves, it offers vast potential for new applications and innovations in food supply chain. From smart cities to industrial automation, healthcare to environmental monitoring, the versatility of IoT applications is reshaping our world, making it imperative to delve into the multifaceted dimensions of this technological revolution (Maulana et al., 2021). Food safety is a global concern, and a reliable Food Traceability System (FTS) is essential to address this issue (Chopra & Pathrotkar, 2024). Advancing food safety through IoT involves the implementation of real-time monitoring and control systems to enhance the quality and safety of food products across the supply chain. The integration of IoT technologies offers a promising solution to combat food-borne illnesses by enabling continuous monitoring of food quality parameters (Adisa et al., 2024). Now a days people are more conscious about the food they buy. They seek assurance and transparency when selecting food products. To meet this demand, it's crucial to establish trustworthy end-to-end transparency in the food supply chain. This transparency enables consumers to authenticate the origin of food items and trace the entire journey from farm to fork. By ensuring this transparency, we build consumer confidence in the safety, quality, and ethical sourcing of food products. Ultimately, providing transparency supports informed consumer choices and encourages sustainable practices within the food industry. sThe acquaintance of the food industry with the IoT in agriculture enables farmers, suppliers, processors, retailers, and consumers to make informed decisions. Moreover, IoT assists food industries with supply chain traceability, food safety, and accountability. Besides, the IoT network significantly cuts down wastage, expenses, and risks associated with the process.

Importance of IOT in Food Safety:

The significance of Internet of Things (IoT) applications lies in their transformative impact across diverse sectors, ushering in an era of interconnected devices and data-driven decision-making. In the realm of healthcare, IoT facilitates remote patient monitoring, improving treatment outcomes and reducing healthcare costs. In smart cities, IoT applications enhance urban efficiency by optimizing resource allocation and enhancing public services. In agriculture, IoT sensors provide real-time data on soil conditions and crop health, optimizing agricultural practices. Industrial IoT revolutionizes manufacturing processes through predictive maintenance and operational efficiency. The integration of IoT into daily life extends to smart homes, wearable devices, and transportation, fostering convenience and safety. Overall, the pervasive influence of IoT applications underscores

their role in fostering efficiency, innovation, and improved quality of life across various domains (Prakash & Kumari, 2024).

1. Improved Traceability:

Radio Frequency Identification (RFID) stands out as a widely used auto-identifying technique for tracking and monitoring items in traceability systems. RFID proves highly effective in diverse supply chains and has been successfully employed in decision support systems and real-time monitoring for perishable products. Additionally, wireless sensor networks (WSNs) play a crucial role in monitoring temperature to ensure the freshness integrity of perishables across the logistical across logistical symphony.

Fig1: Internet Of Things-Based Food Traceability System

Yet, real-world scenarios may present challenges such as network or hardware issues, leading to data loss or corruption from sensors. In such cases, implementing data mining techniques becomes essential to interpolate missing sensor data, ensuring the reliability of the information.

2. Enhanced Safety Monitoring:

In the realm of IoT, devices are constantly monitoring vital factors like temperature, humidity, and real-time conditions. Previously, the quality of transported food items could only be confirmed upon delivery. Now, food industries seeking high-quality products equipped with temperature and humidity sensors can access real-time data on the condition of food items during transit. This capability enhances control over food quality throughout the supply chain, empowering industries to maintain higher standards and ensure customer satisfaction.

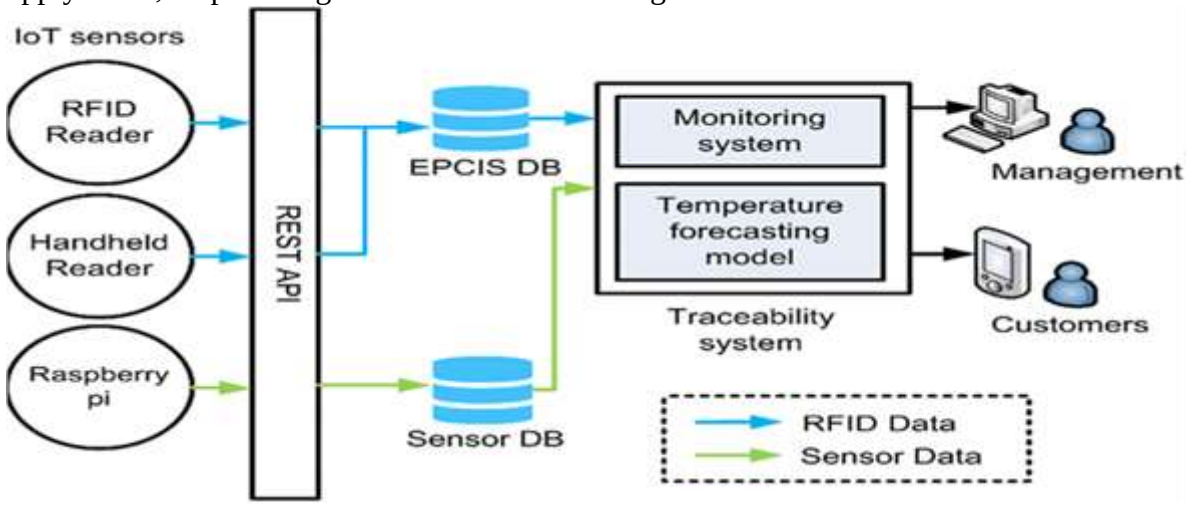

Fig 2: Potential of IoT in Food Safety Industry in India

The integration of IoT in agriculture has empowered stakeholders across the food industry, including farmers, suppliers, processors, retailers, and consumers, to make informed decisions. This technological integration enhances accountability, improves food safety, and facilitates efficient tracking throughout the supply

chain. The IoT network also minimizes risks, reduces costs, and mitigates waste associated with food processing, leading to more sustainable and effective practices in the food industry.

The global food industry faces significant challenges in ensuring food safety throughout the supply chain, including inefficiencies, delays in response to potential hazards, and increased risks of contamination. Traditional methods of monitoring and controlling food safety often lack realtime capabilities and are prone to human error (Temilade Abass et al., 2024).

Figure 3. represents the analysis of data derived from sensors or RFID tags demonstrates how the IoT fosters heightened visibility throughout the supply chain process. This system can also proactively alert workers to incoming deliveries and provide valuable insights into the utilization of warehouse equipment.

Radio frequency identification (RFID) readers scan the barcodes on food packaging and upload them to a cloud storage service, together with the readers' identities and the time of reading. Inventory professionals can determine the locations of tags by knowing where the readers are located.

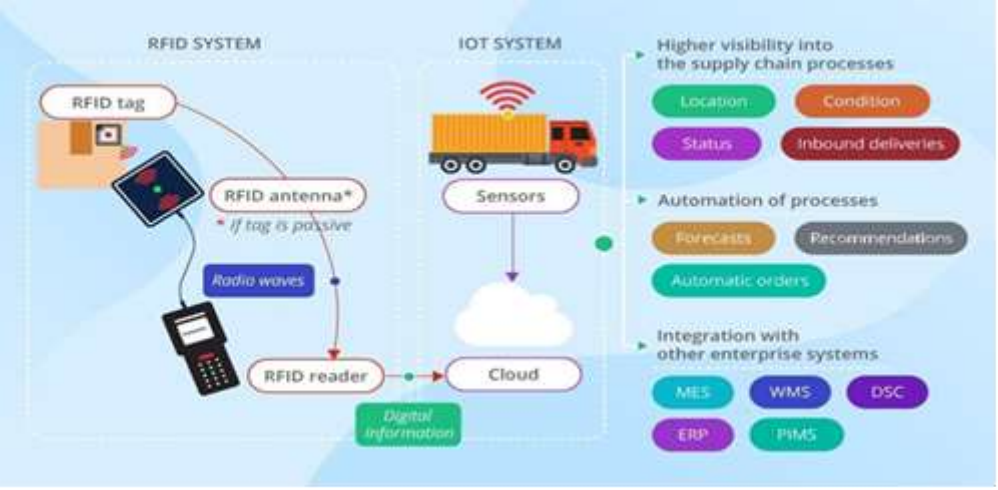

Fig 3: IoT visibility throughout the Supply Chain Process

Benefits of IOT to the food industry:

IoT plays a revolutionary role in food safety management, tracking and traceability, and logistics.

1. Improves Food Safety

The implementation of IoT in this industry has significantly brought down the risks associated with foodborne illness outbreaks. Sensors monitor every stage of production and shipment. Besides, the real-time temperature checking technology assists industries to closely administer every step of food safety procedures to deliver effective cold chain management.

In addition, IoT tracking and traceability features will help discover the origin of contamination early on to avoid further outbreaks.

2. Predicts Accurately

IoT facilitates food manufacturers with an accurate prediction of future issues. For instance, IoT sensors alert about the weather, which can help identify conditions favourable for disease-causing pathogens and foresee potential pest infestations. It significantly helps the manufacturers to plan an action and lower the risk of damage.

3. Reduces Wastage

According to a report by United Nations, 17% of the food produced is wasted every year across the globe. Besides monetary losses, this affects the environment due to the increase of carbon dioxide in the atmosphere.

Internet of Things monitors the condition of food products and sends real-time data to the authorized individual. This way, assigned individuals can track the expiry date of the products and dispose of them promptly. Using IoT, manufacturers can trigger refrigeration monitoring alerts when the storing temperature fluctuates reducing food wastage.

Additionally, IoT can play a crucial role in improving the expenses of inventory with real-time information.

4. Maintains Supply Chain Transparency

IoT also helps food manufacturers to acquire customer loyalty. Implementation of IoT tracking and traceability throughout the entire supply chain maintains transparency for consumers. IoT technology makes it convenient for both manufacturers and consumers to track food items, even though international and domestic rules may amplify the intricacy of the supply chain.

Besides, transparency has some additional benefits, such as effective inventory management, cost-effectiveness, and more. Manufacturers can identify the issue and solve the incompetence in the supply chain accordingly.

5. Improves Logistics

IoT technology effectively facilitates supply chain traceability. It helps keep track of the processes from storage to shipping to the sale points. Radio Frequency Identification (RFID) transmitters and GPS serve the purpose efficiently. Also, the advanced RFID tracking technology allows better visibility of the food supply chain. It gathers the relevant information to track the location of the food item with GPS, which helps stakeholders evaluate their performance globally.

6. Reports Compliance Automatically

Besides quality assurance, IoT provides accurate and timely reports to respective regulators. It helps to reduce working hours and chances of errors on confidential administrative tasks. The smart sensors and connected devices streamline monitoring processes. In addition, a pre-configured HACCP (Hazard Analysis Critical Control Point) checklist helps maintain continuous data regarding production, manufacturing, transportation, and food storage.

Applications of IOT in Food Supply Chain:

Currently, many IoT applications depend on the type of industry that they use. They can be classified according to the type of network availability, coverage, scale, heterogeneity, repeatability, user engagement, and impact.

1)Unique FSCs have wide geographical coverage, complex operational processes with a large number of stakeholders throughout the chain, and provide insights into food quality, operational efficiency, and food safety.

2)The availability of nutritious food is more important to everyone than any economic, social, or environmental development.

3)The world's population is projected to reach nine billion by 2050, which will completely change the world and also put a lot of pressure on FSCs.

4)However, the development of IoT technology is likely to provide encouraging solutions.

5)The IoT can play a role in the functioning of every part of the FSC, from farms to food production, processing, storage, distribution, and consumption.

6)The IoT can address tracking, visibility, transparency, and controllability challenges.

7)It can also address safety, efficiency, transparency, and stability are some of the features required in the FSC.

CONCLUSION

In conclusion, implementing IoT for food safety in India poses multifaceted challenges that require careful consideration. These challenges include limitations in infrastructure, financial constraints, interoperability issues, data security concerns, and regulatory complexities. However, addressing these challenges is vital to fully leverage IoT's potential in enhancing food safety across the supply chain. To achieve this, collaborative efforts involving government bodies, industry stakeholders, and researchers are necessary. Together, we can develop innovative solutions, promote standardization, and establish a supportive regulatory framework. By overcoming these obstacles, India can create a resilient and technologically advanced food safety ecosystem that prioritizes the well-being of its population amidst evolving food supply chain dynamics.

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