Revista Ibero-Americana Multidisciplinary Scientific Journal of Knowledge.
ISSN: 2675-9128. Sao Paulo-SP.

Year II, v.1 2022. | submission: 05/11/2022 | accepted: 05/13/2022 | publication: 05/15/2022

The Role of the Internet of Things (IoT) in Monitoring Water Quality and Temperature Food during Transport

The Role of the Internet of Things (IoT) in Monitoring Food Quality and Temperature During Transportation

Author: Jose Flavio Coutinho de Souza

Graduated in Data Processing, from the University of the Amazon

SUMMARY

This article analyzes the application of the Internet of Things (IoT) in the monitoring of perishable foods during transportation, focusing on the preservation of temperature and product quality. Based on a literature review and case studies, the operational advantages of IoT in cold chain control, traceability, loss reduction and improvement of food safety are discussed. The technical and ethical challenges related to infrastructure, standardization and data privacy are also addressed. The research aims to demonstrate how the strategic use of sensors and connected systems can transform food logistics and contribute to more sustainable supply chains.

Keywords: Internet of Things; Food Transportation; Cold Chain; Food Logistics; Traceability.

ABSTRACT

This paper analyzes the application of the Internet of Things (IoT) in monitoring perishable food during transportation, focusing on temperature control and product quality. Through a literature review and case studies, the paper discusses the operational benefits of IoT in cold chain management, traceability, loss reduction, and improved food safety. It also addresses technical and ethical challenges related to infrastructure, standardization, and data privacy. The study aims to demonstrate how the strategic use of sensors and connected systems can transform food logistics and contribute to more sustainable supply chains.

Keywords: Internet of Things; Food Transportation; Cold Chain; Food Logistics; Traceability.

1. Introduction

The increasing complexity and globalization of perishable food supply chains have required the development of innovative technologies that enable rigorous monitoring of transport conditions. Among these technologies, the Internet of Things (IoT) stands out, which, through the interconnection of smart devices and sensors, enables the

real-time monitoring of essential parameters such as temperature, humidity and location of products. Food transportation is a critical step in ensuring the safety and quality of products to the end consumer, with maintaining the cold chain being one of the main logistical challenges faced by companies in the sector (SANTOS; OLIVEIRA, 2020).

The concept of IoT, introduced in the last decade, encompasses the integration of physical objects with the internet, enabling the continuous exchange of data without direct human intervention. In the context of food logistics, this technology enables remote monitoring, process automation and decision-making based on accurate and up-to-date data, resulting in greater operational efficiency and reduced losses (MARTINS et al., 2019). These characteristics are particularly relevant for the food sector, where inappropriate temperature variations can compromise the microbiological integrity of food, leading to risks to public health and significant financial losses.

In addition to the operational benefits, the use of IoT in food transportation also brings technical challenges related to the technological infrastructure required for its operation. Implementation requires robust devices, reliable connectivity, and efficient integration with data management systems. Furthermore, ethical and regulatory issues associated with the privacy and security of data collected by sensors have gained relevance, imposing the need for clear policies and strict compliance by the organizations involved (LIMA; PEREIRA, 2021).

This article aims to present a detailed analysis of the role of IoT in monitoring the quality and temperature of food during transportation, based on a careful literature review and selected case studies, all dated up to December 2021. Through this investigation, we intend to highlight the main operational advantages, technological challenges and impacts on the sustainability of the logistics chain, in addition to discussing the future perspectives of this technology for the food sector.

The relevance of the topic is justified by the growing consumer demand for transparency and quality in the food production chain, combined with the need to reduce waste and optimize logistics resources. The adoption of IoT is therefore an essential strategy for strengthening food safety, regulatory compliance and the competitiveness of companies in the globalized market (FERREIRA; ALMEIDA, 2020).

Finally, the study emphasizes the importance of multidisciplinary integration between technology, logistics and public policies for the consolidation of intelligent and efficient monitoring systems. It is also considered that the advancement of IoT can contribute significantly to the development of more sustainable and resilient supply chains, promoting economic, social and environmental benefits, aligned with the global objectives of sustainable development (UN, 2015).

2. Literature Review

The scientific literature related to the application of the Internet of Things (IoT) in food logistics has grown significantly in the last decade, reflecting the importance of this technology for the modernization of supply chains and increased food safety. Several authors highlight IoT as a key element for the digitalization of logistics processes, especially in maintaining the cold chain, which is essential to preserve the quality of perishable foods during transportation (SILVA; COSTA, 2019).

The cold chain is defined as the set of storage, handling, and transportation operations carried out under strict temperature-controlled conditions. Failure to do so can result in loss of quality and increased microbial proliferation, which compromises food safety and poses risks to the health of the end consumer (GOMES; ROCHA, 2018). In this context, the use of connected sensors and remote monitoring systems via IoT allows for more precise and efficient management, enabling real-time monitoring and rapid identification of deviations that may compromise product integrity (MARTINS et al., 2019).

Case studies show that the implementation of IoT systems in the logistics chain results in a significant reduction in food losses and waste. For example, the use of electronic temperature labels and environmental sensors in refrigerated vehicles enables continuous tracking and the generation of automatic alerts in the event of anomalies, which increases reaction capacity and reduces losses (FERREIRA; ALMEIDA, 2020). In addition, the integration of collected data with analytical platforms enables the optimization of routes and the improvement of logistics planning, increasing operational efficiency (LIMA; PEREIRA, 2021).

However, the technical challenges for IoT adoption are significant and include the need for robust infrastructure, reliable connectivity in remote areas, and interoperability between different devices and systems. Limitations in network coverage, especially in hard-to-reach regions, can compromise real-time monitoring, requiring hybrid solutions and data storage and synchronization strategies (SANTOS; OLIVEIRA, 2020). In addition, the standardization of communication protocols and information security are critical points to ensure the integrity and confidentiality of transmitted data (MARTINS et al., 2019).

Ethical aspects related to the privacy of data collected by IoT sensors are also the subject of discussion in the literature. The increasing digitalization of the supply chain implies the processing of large volumes of information, including sensitive data that can affect the competitiveness of companies and the privacy of those involved in the logistics process (LIMA; PEREIRA, 2021). Thus, the adoption of clear data governance policies and compliance with regulatory standards are essential to ensure legal compliance and stakeholder trust.

In addition to the immediate benefits in logistics operations, IoT in the cold chain has been associated with positive impacts on environmental sustainability. The reduction of losses and waste

contributes to reducing the excessive use of natural resources, reducing greenhouse gas emissions and making better use of agricultural and industrial production (FERREIRA; ALMEIDA, 2020). Therefore, IoT is configured not only as a technological instrument, but as a strategic element for sustainable development in the food sector.

3. Applications of the Internet of Things in Food Quality and Temperature Monitoring

The application of the Internet of Things (IoT) to monitor the quality and temperature of food during transportation represents a significant advance for the logistics sector, allowing greater control, safety and efficiency throughout the supply chain. This technology uses smart sensors capable of measuring, recording and transmitting data in real time, ensuring that the environmental conditions essential for food preservation are maintained from the origin to the final destination (SANTOS; OLIVEIRA, 2020).

Temperature sensors connected via IoT enable constant monitoring of the cold chain, which is essential for preserving perishable products such as fruits, meats, dairy products and medicines. Automated communication between these devices and management platforms allows for the rapid identification of deviations and the triggering of alerts, which reduces the response time for correcting errors and prevents product loss (MARTINS et al., 2019). In addition, the analysis of historical data obtained by the sensors enables the optimization of routes and the improvement of logistics processes, generating cost savings and increased service quality.

Another relevant application of IoT is in food traceability, which is essential to ensure transparency and food safety. Through electronic tags (RFID) and integrated sensors, it is possible to track the trajectory of products throughout the chain, documenting environmental conditions and critical events during transportation. This traceability strengthens consumer confidence and facilitates the rapid identification of problems in cases of contamination or recalls, promoting a more effective response and minimizing risks to public health (FERREIRA; ALMEIDA, 2020).

The integration of IoT with artificial intelligence systems and big data analysis has enhanced the predictive capacity of logistics operations. Algorithms can identify behavior patterns, predict failures, and suggest preventive actions, increasing the level of control and safety in food transportation (LIMA; PEREIRA, 2021). This technological convergence represents an evolution from traditional logistics to logistics 4.0, characterized by digitalization, automation, and greater data-based decision-making capacity.

On the other hand, the adoption of these technologies also faces challenges, including the need for significant investments in technological infrastructure, personnel training and adaptation of organizational processes. The heterogeneity of devices and the absence of universal standards make interoperability difficult, requiring customized solutions and collaborative efforts between suppliers, carriers and customers (SILVA; COSTA, 2019). In addition,

Furthermore, ensuring cybersecurity is essential to protect systems against attacks that could compromise data integrity and the continuity of operations.

In short, the application of IoT to monitor food quality and temperature during transportation is a strategic tool for the logistics sector, providing significant gains in efficiency, safety, and sustainability. The proper implementation of these solutions requires careful planning and overcoming technical and organizational challenges, but their potential to transform supply chains is widely recognized and supported by the literature until 2021.

4. Operational Benefits of IoT in Food Transportation

The incorporation of the Internet of Things (IoT) into food transportation has provided a series of operational benefits that directly impact the efficiency, safety, and quality of the logistics chain. Among the main gains, real-time monitoring of environmental conditions stands out, especially temperature, a critical factor for the preservation of perishable products and the prevention of microbial proliferation that can compromise the health of consumers (SANTOS; OLIVEIRA, 2020).

Continuous monitoring allows for the immediate identification of any deviations, enabling rapid interventions to correct transportation conditions. This significantly reduces the occurrence of losses and waste, which represent substantial economic losses for companies and consumers, in addition to negative environmental impacts due to the improper disposal of food (MARTINS et al., 2019). Studies indicate that the adoption of IoT can reduce losses in the cold chain by up to 30%, standing out as a strategic technology for the sector (FERREIRA; ALMEIDA, 2020).

Furthermore, IoT contributes to the optimization of logistics through the analysis of collected data, allowing for more efficient route planning and better use of available resources, such as vehicles, personnel and time (LIMA; PEREIRA, 2021). This data-based management results in reduced operating costs and increased competitiveness of companies in the market, a factor that is especially relevant in a globalized and highly competitive context.

Another important benefit is the improvement in supply chain traceability and transparency. The integration of IoT sensors with management systems enables the generation of detailed reports and complete documentation of transportation conditions, facilitating compliance with regulatory standards and agile response to potential problems, such as recalls or contamination (GOMES; ROCHA, 2018). This transparency strengthens the trust of consumers and regulatory authorities, which is essential for the reputation of companies.

Additionally, IoT promotes sustainability by promoting the reduction of food waste and the more efficient use of logistics resources. Reducing losses prevents excessive consumption of energy, water and raw materials in the production of food that would otherwise be discarded, aligning with the principles of the Sustainable Development Goals.

RCMOS - Multidisciplinary Scientific Journal of Knowledge.
ISSN: 2675-9128. Sao Paulo-SP.

(SDG) of the United Nations (UN, 2015). In this way, technology contributes to the environmental and social responsibility of organizations.

Finally, the application of IoT can improve the end consumer experience by ensuring that the products purchased maintain their quality and safety from production to the point of sale. The ability to provide detailed information about the origin and transportation conditions of food also responds to the growing demand for transparency and social responsibility in production chains (FERREIRA; ALMEIDA, 2020). Thus, IoT not only improves companies' internal processes, but also adds value to the brand and the relationship with the consumer.

5. Technical and Technological Challenges in Implementing IoT in Food Transportation

The implementation of the Internet of Things (IoT) in food transportation, although it brings numerous benefits, presents a series of technical and technological challenges that need to be addressed to ensure its successful adoption. Among the main obstacles are the infrastructure required to support the collection, transmission and storage of data in real time, especially in environments with limited or intermittent connectivity (SANTOS; OLIVEIRA, 2020).

The dependence on stable networks, such as 4G, 5G or Wi-Fi, is a critical point, since food transportation often occurs on remote routes or in countries with poor telecommunications infrastructure. In these situations, IoT must rely on mechanisms for temporary local storage and subsequent data synchronization, which can compromise the immediacy of information and, consequently, the ability to react quickly to failures (MARTINS et al., 2019).

Furthermore, the heterogeneity of devices used in the logistics chain represents a major challenge. The lack of standardization in communication protocols and software platforms makes it difficult to integrate different sensors and monitoring systems, requiring customized solutions and additional investments in technological development (LIMA; PEREIRA, 2021). This fragmentation can impact the scalability and interoperability of systems, limiting the scope of IoT benefits.

Another challenge is to ensure the security and privacy of data collected by IoT devices. The growing volume of sensitive information demands the implementation of strict data protection policies, as well as the use of advanced encryption, authentication and access control techniques (FERREIRA; ALMEIDA, 2020). The vulnerability of systems can result in cyberattacks, compromising data integrity and the continuity of logistics operations.

The cost of implementing and maintaining IoT solutions is also a barrier for many companies, especially small and medium-sized ones. Investing in sensors,

communication systems, analytical platforms and staff training requires careful financial planning and return on investment (ROI) assessment. However, research indicates that gains in efficiency and loss reduction tend to outweigh initial costs in the medium and long term (GOMES; ROCHA, 2018).

Finally, professional training is a critical factor for the success of IoT in food logistics. It is necessary to develop technical skills for the operation, maintenance and analysis of systems, as well as an organizational culture oriented towards innovation and the strategic use of data (SILVA; COSTA, 2019). Resistance to change and lack of knowledge can delay adoption and limit expected results.

6. Ethical and Regulatory Aspects Related to the Use of IoT in Food Transportation

The use of the Internet of Things (IoT) in food transportation, in addition to technical and operational aspects, involves ethical and regulatory issues that are fundamental for its responsible and sustainable implementation. The growing volume of data generated by connected devices raises concerns regarding privacy, information security and the governance of data collected throughout the logistics chain (LIMA; PEREIRA, 2021).

Data privacy refers to the protection of personal and sensitive information that may be associated with the transportation and traceability of food, including data from suppliers, carriers and consumers. The absence of clear policies can result in misuse of information, damaging trust between actors in the chain and, in extreme cases, leading to legal implications for organizations (FERREIRA; ALMEIDA, 2020).

Furthermore, cybersecurity is a critical aspect, since IoT systems are susceptible to attacks that can compromise the integrity, confidentiality and availability of data. Attacks such as hacking, device hijacking and information manipulation can cause operational failures, financial losses and risks to food safety (MARTINS et al., 2019). Therefore, the adoption of strict security protocols and constant technological updates are essential to mitigate these risks.

In the regulatory sphere, different countries have developed specific legislation for data protection, such as the General Data Protection Regulation (GDPR) in the European Union and the General Data Protection Law (LGPD) in Brazil. These standards impose obligations on companies regarding the collection, storage, processing and sharing of information, demanding compliance and regular audits to ensure legal compliance (GOMES; ROCHA, 2018).

Additionally, food safety regulations require companies to adopt practices that ensure food integrity throughout the logistics process. The use of IoT can be seen as a facilitating instrument for compliance with these standards, providing accurate and reliable records for inspection and auditing (SANTOS;

OLIVEIRA, 2020). However, it is essential that technological implementation is aligned with current legal requirements.

Finally, the importance of transparency and ethics in the management of collected data is highlighted. Organizations must ensure that information is used exclusively for the stated purposes and that the rights of those involved are respected, promoting trust and cooperation among all participants in the chain (LIMA; PEREIRA, 2021). Ethics in the use of IoT is, therefore, an indispensable component for the sustainable and responsible development of the food sector.

7. Future Perspectives and Impacts of IoT on the Sustainability of the Food Logistics Chain

The expansion of the Internet of Things (IoT) in the food transportation sector has the potential to bring about significant transformations, not only from an operational point of view, but also in terms of environmental, economic and social sustainability. The trend is that, with technological advancement, IoT will be incorporated in a more integrated and intelligent way into supply chains, promoting increasingly efficient and responsible logistics (FERREIRA; ALMEIDA, 2020).

From an environmental perspective, IoT contributes to reducing food waste, one of the major global challenges today. Food waste represents an inefficient use of natural resources, such as water, energy and land, in addition to emitting greenhouse gases during the decomposition of organic waste (UN, 2015). Accurate monitoring of temperature and transportation conditions makes it possible to preserve the quality of products and minimize these losses, in line with sustainable development goals.

Economically, IoT tends to boost companies' competitiveness by optimizing logistics processes and reducing operating costs associated with product deterioration and route inefficiency (SANTOS; OLIVEIRA, 2020). The ability to collect and analyze data in real time favors more informed decisions, improved planning, and rapid response to problems, resulting in greater profitability and resilience in the face of market challenges.

Socially, the adoption of IoT promotes greater food safety and transparency for consumers, who increasingly demand reliable information about the origin and quality of the food they purchase (LIMA; PEREIRA, 2021). Improved traceability
enables the rapid identification and isolation of contaminated batches, preventing risks to public health and strengthening confidence in the production chain.

Furthermore, future prospects include the integration of IoT with other emerging technologies, such as artificial intelligence, blockchain and big data, forming digital ecosystems capable of further automating and optimizing food logistics (MARTINS et al., 2019).
This technological convergence should provide autonomous, predictive and

adaptive, which respond in real time to environmental and logistical variables, promoting a more sustainable and resilient supply chain.

However, for these perspectives to become a reality, it is necessary to overcome current challenges by investing in technological infrastructure, professional training and the development of public policies that encourage innovation and ensure security and ethics in the use of data (FERREIRA; ALMEIDA, 2020). The role of governments, academic institutions and the private sector is essential to create an environment conducive to the responsible expansion of IoT in food transportation.

In short, the Internet of Things is emerging as a key element for the modernization and sustainability of food supply chains, with impacts that transcend the technological aspect and reach economic, social and environmental dimensions. The continuous evolution of this technology and its integration with other innovations promise a future in which food transportation will be increasingly safe, efficient and aligned with the principles of sustainable development.

8. CONCLUSION

The Internet of Things (IoT) has established itself as a fundamental technology for monitoring the quality and temperature of food during transportation, contributing significantly to the modernization and efficiency of food logistics chains. Through the integration of smart sensors, connectivity and analytical platforms, IoT enables real-time monitoring of environmental conditions, ensuring the maintenance of the cold chain and, consequently, the safety and integrity of perishable products (SANTOS; OLIVEIRA, 2020).

The operational benefits of IoT are broad and include reducing losses and waste, optimizing logistics routes, improving traceability, and strengthening regulatory compliance. These gains are reflected not only in the savings for companies, but also in protecting public health and promoting environmental sustainability, aligning with global sustainable development goals (FERREIRA; ALMEIDA, 2020).

However, the full adoption of IoT faces technical challenges, such as the need for robust infrastructure, reliable connectivity and interoperability between heterogeneous devices, as well as ethical and regulatory issues regarding the privacy and security of collected data. Overcoming these obstacles requires financial investments, professional training and the establishment of clear governance and information security policies (LIMA; PEREIRA, 2021).

Furthermore, the evolution of IoT is directly linked to its integration with other emerging technologies, such as artificial intelligence and blockchain, which enhance the capacity for analysis and automation of logistics processes. This technological convergence

promises to transform food logistics, making it more intelligent, adaptive and sustainable (MARTINS et al., 2019).

Therefore, for the full potential of IoT to be achieved in food transportation, a joint effort between the public, private and academic sectors is essential, aiming to foster innovation, ensure security and promote ethics in the use of data. The strategic implementation of IoT represents a decisive step towards building more resilient, transparent supply chains that are aligned with contemporary socio-environmental challenges.

REFERENCES

FERREIRA, JP; ALMEIDA, RS Applications of the Internet of Things in food logistics: impacts on efficiency and sustainability. *Brazilian Journal of Logistics,* v. 18, n. 2, p. 45-62, 2020.

GOMES, AL; ROCHA, MF The cold chain in food logistics: challenges and emerging technologies. *Journal of Production Engineering,* v. 15, n. 3, p. 112-129, 2018.

LIMA, TC; PEREIRA, FS Ethical and regulatory aspects of the use of the Internet of Things in supply chains. *Journal of Law and Technology,* v. 7, n. 1, p. 78-94, 2021.

MARTINS, VR; SILVA, PJ; ALMEIDA, FL Cold chain monitoring with the Internet of Things: challenges and opportunities. *Journal of Technology and Management,* v. 9, n. 1, p. 34-49, 2019.

UN – UNITED NATIONS. Sustainable Development Goals. Available at: https://www.un.org/sustainabledevelopment/ .

SANTOS, DM; OLIVEIRA, LF Applications of the Internet of Things for the transportation of perishable foods. *Journal of Logistics and Technology,* v. 22, n. 4, p. 55-70, 2020.

SILVA, RT; COSTA, MA Technological integration in food logistics: the role of IoT. *Journal of Technological Sciences,* v. 10, n. 2, p. 88-103, 2019.