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Improving Cold Chain Efficiency And Quality Of Perishable Food Products Using IOT

Mr. Shreyas Kulthe, Mr. Sahil Ghag, Ms. Purvi Kale, Ms. Vineeta Philip
Department of Electronics and Telecommunication Engineering,
AISSMS Institute of Information Technology, Pune 411001,India

Abstract:

Through the integration of IoT technology, the effort tackles major issues with cold chain management of perishable food items. IoT sensors that track temperature, humidity, and other parameters in real-time allow for proactive steps to be taken to ensure product quality. By identifying and mitigating threats using predictive insights generated by advanced analytics, the likelihood of spoiling is decreased. Process optimization through automation reduces the possibility of human mistake and spoiling while in storage and transit. Through its potential to enable targeted recalls and guarantee traceability from farm to fork, blockchain technology improves food safety. Utilizing energy-efficient techniques to reduce waste and carbon emissions is a major component of sustainability. The project's main goal is to completely transform cold chain management by building a robust, long-lasting, and effective system that guarantees food safety.

Keyword:

Perishable food goods, automation, blockchain technology, sensors, predictive insights, cold chain management, and sustainability

Introduction:

Safety Maintaining the quality and safety of perishable food items along the supply chain is essential for the global food business. Managing the cold chain—the continuous sequence of refrigerated production, storage, and distribution procedures that guarantee perishable goods remain at the proper temperatures from farm to fork—is a crucial component of this difficulty. Inadequate cold chain management can lead to serious financial losses, a rise in food waste, and a compromise in food safety.The use of Internet of Things (IoT) technology is one potential remedy for these problems. IoT's automation, data analytics, and real-time monitoring capabilities have the potential to completely change cold chain management. Throughout the supply chain, stakeholders can obtain fresh insights into temperature, humidity, and other critical aspects affecting the quality of perishable food commodities by implementing sensors and linked devices. With the use of IoT technology, this project seeks to enhance the efficiency and quality of the cold chain for perishable food items.

1. Real-Time Monitoring: Internet of Things (IoT) sensors should be placed at strategic locations along the cold chain to continuously monitor temperature fluctuations and other environmental factors. Proactive intervention to stop temperature excursions and guarantee adherence to quality requirements is made possible by this real-time data collecting.
2. Data analytics and predictive insights: Managing the massive volumes of data gathered by Internet of Things devices through the use of sophisticated analytics techniques. Predictive models can foresee potential problems in the cold chain by analyzing past trends and patterns. This enables proactive measures to be taken in order to preserve the integrity and quality of the product.
3. Process Optimization and Automation: Temperature control, inventory management, and logistical processes can all be automated by integrating Internet of Things-enabled devices with the current cold chain infrastructure. This optimization eliminates the risk of human error, expedites procedures, and lessens the chance that goods would deteriorate while being stored and transported.
4. Traceability and Transparency: An unchangeable record of product movement along the cold chain can be created using blockchain technology. By enabling stakeholders to promptly determine the underlying cause of contamination incidents or quality problems, clear traceability promotes customer confidence and facilitates targeted recalls.

Literature Review:

The cold chain, a crucial component in the food supply chain, maintains perishable items at the right temperature from the point of production to the point of consumption. But problems like temperature swings, a lack of real-time surveillance, and ineffective logistics have resulted in low-quality food that is wasted. The purpose of this literature evaluation is to determine how Internet of Things (IoT) technologies could enhance product quality and cold chain efficiency. The application of Internet of Things (IoT) technologies in the perishable food sector has great potential to raise the bar for cold chain logistics standards and efficiency.
Nevertheless, temperature swings, ineffective operations, and insufficient monitoring are common problems with traditional cold chain management systems, which can result in food loss, degradation, and lower-quality products. Stakeholders in the cold chain industry may be able to overcome these obstacles and transform the handling, storing, and shipping of perishable food products by utilizing IoT technology. IoT-enabled systems improve product quality assurance, operational efficiency, and sustainability through automation, greater traceability, real-time monitoring, and predictive analytics. The real-time monitoring capabilities of IoT sensors enable stakeholders to continuously monitor environmental factors like temperature and humidity.

All things considered, there is a lot of potential for the integration of IoT technology to improve cold chain logistics, as well as quality, productivity, sustainability, and supply chain assurance of the integrity and safety of perishable food items. It appears that cold chain logistics has a promising future full of opportunities for advancement and innovation as IoT solutions become more common and technology progresses. Processes in cold chain logistics must be optimized, and this requires automation. Real-time inventory management, temperature control, and transportation route optimization are made possible by IoT-enabled automation solutions. They also guarantee constant product quality, cut down on errors, and lessen the need for manual work. Furthermore, blockchain technology improves the cold chain's traceability and transparency.
Using IoT technologies in cold chain logistics not only increases product quality and operational efficiency, but it also promotes sustainability. IoT-driven cold chain solutions maintain the safety and integrity of perishable food items while optimizing resource utilization, cutting energy consumption, and removing waste. This helps achieve environmental sustainability goals.

IoT considerably raises the quality and efficiency of the cold chain, but data security, interoperability, and scalability remain issues that need to be resolved. To effectively leverage IoT in the cold chain business and overcome these obstacles, stakeholders must work together, establish protocols, and conduct continuous research and development.

An overview of the circumstances and viewpoints surrounding energy efficiency in cold food supply chains Many factors influencing the adoption of EEMs in CSCs in the food industry were highlighted in the literature research. The research methodology selected to investigate this issue is predicated on the idea that the structural characteristics of CSCs (#2), the perspectives of NEBs (#3), and the functioning of BOAs (#4) all

have an impact on the role of energy efficiency (#1). There are several elements in each of these categories that could affect the uptake of EEMs. To investigate these concerns, two phases of research were conducted.

Research on the Construction of Cold Chain Logistics Intelligent System Based on 5G

1. Requirements Gathering: Identify stakeholder needs and system requirements for the Cold Chain Logistics Intelligent System (CCLIS).
2. System Design: Design the architecture, sensor deployment strategy, network infrastructure, data management, analytics, and control algorithms.
3. Prototype Development: Procure hardware, develop software, and integrate components to build a functional CCLIS prototype.
4. Pilot Deployment: Test the CCLIS in a real-world cold chain logistics environment and evaluate its performance.

Food cold chain management: what we know and what we deserve

To systematically record the trends, traits, and developments identified in academic literature relevant to a certain sector or topic, bibliometric analysis is a powerful and useful technique that may be used to many different domains (Ertz and Leblanc-Proulx, 2018). It provides an organized, thorough compilation of fundamental and important literature about well-known journals, associations, and nations, as well as prolific writers and esteemed journals (Merigo et al., 2016; Gaviria-Marin et al., 2019). In this work, scientific mapping approaches and research performance assessment are combined with bibliometric analysis (Noyonset al., 1999; Cobo et al., 2011).

Aim and Objectives:

The present cold chain management system for perishable food commodities is inefficient and provides inadequate quality assurance due to food degradation and decreased safety, resulting in large financial losses. Predictive analytics, automation, and real-time monitoring are required to overcome these obstacles along the cold chain. This highlights the importance of utilizing IoT technologies. The goals are to minimize waste, make the best use of available resources, and guarantee that the highest quality standards are maintained over the whole production and consumption process.

1. Increasing Efficiency: By deploying Internet of Things sensors and devices along the cold chain, temperature monitoring, inventory control, and transportation will all be improved. Real-time analytics and data collecting increase overall operating efficiency and enable proactive management that minimizes delays and prevents temperature swings.

   2. Ensuring Product Quality: Perishable food items are kept at ideal temperatures throughout the supply chain thanks to IoT technology's continuous monitoring of several environmental parameters like temperature, humidity, and air quality. Reducing spoilage, extending shelf life, and preserving product quality eventually result in happier customers and less food waste.
2. Promoting Transparency and Traceability: By leveraging blockchain technology, the objective is to offer immutable, transparent records of product movement inside the cold chain. This facilitates the tracking of perishable goods from farm to fork and increases traceability for all parties involved. In the event of contamination or poor quality, transparent traceability facilitates targeted recalls and ensures food safety.

   4. Optimizing Resource Usage: IoT-driven optimization strategies aim to improve cold chain sustainability by reducing waste and energy use. By making the optimal decisions about temperature settings, route planning, and storage conditions, stakeholders may reduce their impact on the environment while maintaining product quality and safety.

Objective:-

1. Real-Time Monitoring: Continuous monitoring of the temperature and other important aspects using IOT sensors.

2. Predictive analytics: Machine learning algorithms are used in the model for collection and analysis of the collected data for effective and efficient decision making.
3. Automation and Optimization: To automate and optimize the model we have used required sensors and machine learning algorithm. Along with the increased optimization it also automates the model so that no human intervention is needed.

4. Traceability and Transparency: It provides traceability and transparency which make sure that the food products are maintained in the proper safe temperature and safely delivered to the station.

METHODOLOGY:-

1. Needs assessment: We make sure that all the components are placed in proper manner so and so that the working of the model will be perfect if anything is need to be changed then it is done according to the requirement of the system.

2. Building an Internet of Things infrastructure is the most important step as we are making a automated model . So building proper IOT infrastructure os important along with machine learning part.

3. Sensor Deployment: This step makes sure that all the required sensors are placed in the proper place. The sensors such as camera, IR sensor which play important role they should be placed in proper location for detection of the object.
4. After this the data is collected through this sensors and analysed for decision making by the machine learning algorithm to set the required temperature.

5. Data Analytics and Insights: Make use of machine learning algorithms and other data analytics approaches to assess the collected data and generate insightful findings. Look for patterns, trends, and anomalies in temperature fluctuations and product conditions to enhance cold chain operations and foresee potential issues.

Hardware Specifications:

1. Peltier Module: Peltier module structure has two types of semiconductor elements arranged in tandem sandwiched between copper substrates. When electricity is passed through the module, electrons move in one element and positive holes move in the other element, this is called the "Peltier effect." This allows one side of the substrate to absorb heat and the other to radiate heat, so the hot and cold sides to be switched depending on the current direction. It can also be used as a thermoelectric power generation module using the "Seebeck effect" in which a current flows by applying a temperature difference on both sides of the Peltier module.
2. Motor Driver: Motor driver is used to control motion of a motor and its direction by feeding current accordingly. Output of a motor driver is in digital form so it uses PWM (Pulse Width Modulation) to control speed of a motor. Motor Driver are basically current amplifiers followed by input signals. It can also drive inductive loads such as relays, solenoids, transformer etc.

3. Fan: Fans can be thought of as low pressure air pumps that utilize power from a motor to output a volumetric flow of air at a given pressure. A propeller converts torque from the motor to increase static pressure across the fan rotor and to increase the kinetic energy of the air particles. The motors are typically permanent split capacitor alternating current (AC) induction motors or brushless direct current (DC) motors. We shall now look at this system in more detail.

4. Temperature Sensor: We have used the LM 25 temperature sensor to continuously monitor the temperature inside the container.

Block Diagram :

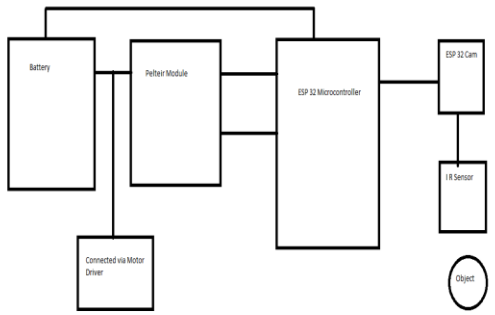

Fig. block diagram

Working :

The proposed algorithm uses Internet of Things technology in a cold chain context to increase the yield and quality of perishable fruits (apple, cucumber, and lemon). Fruits require a certain temperature to be met in order to keep their freshness. For instance, apples, cucumbers, and lemons should all be stored below 3 degrees Celsius, 8 degrees Celsius, and 2 degrees Celsius, respectively.
The Internet of Things (IoT) sensors integrated into cold storage containers are employed in this strategy. These sensors can quickly and accurately regulate the temperature to the ideal level based on the type of fruit that is placed within the container.

Its automated technology reduces the likelihood of human error while ensuring consistent fruit quality over the course of the storage time by doing away with the requirement for manual intervention and upholding perfect storage conditions.
When fruit is placed into the container, the IoT sensor looks for distinguishing characteristics like its barcode to determine what kind of fruit it is. Once the sensor has identified itself, it communicates with the temperature control system to adjust the inside temperature of the container. For example, if an apple is found, its temperature is lowered to less than 3 degrees Celsius to preserve its freshness.

Real-time monitoring is essential to ensure that the temperature remains within the specified range for the whole storage period. Internet of Things (IoT) sensors continuously check the container's temperature and alert users to any anomalies. This makes it possible to stop decaying and solve issues as soon as they arise. Analyzing the data gathered by the Internet of Things sensors can potentially reveal trends and patterns in the variations in temperature over time. This information can be used to ensure more stable conditions and optimize the cold chain management process by adjusting insulation or temperature settings.

Overall, the efficiency and quality of perishable fruits like apples, cucumbers, and lemons can be greatly improved by utilizing IoT technology to automate temperature control and monitoring within cold storage containers. This guarantees that buyers obtain fresh, premium fruit while also lowering the danger of spoiling and food waste.

Flowchart:

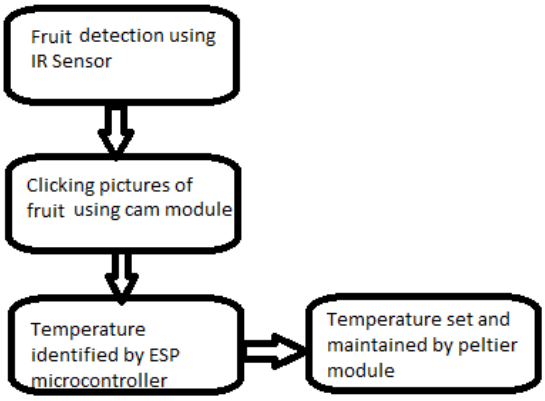

Fig. Flowchart

Explaination:

- The IR sensor detects the fruit inserted inside the container and sends signal to cam midule to take pictures
- Cam module take the pictures of the fruit and sends them to the ESP microcontroller.
- ESP microcontroller trues to match the pictures taken by the cam with the pre installed datasheer of the pictures of various fruits.
- Once the type of fruit is identified then the accurate temperature is identified as it is feeded in the datasheet.
- Upon identification of the temperature an signal is sent to the Peltier Module.
- Peltier module sets the temperature as received from the ESP microcontroller.
- The temperature is maintained throughout until the fruit is removed from the container.

Software Design:

For software we have used Aurdino IDE for programming and Blynk IOT software for displaying the data on the screen. Blynk IOT software is connected to the system via wifi.

Result:

1. Enhanced Efficiency: Use of the IOT technology enhances the overall efficiencnt of the system. All the perishable food products are properly kept under the required temperature and delivered. The machine learning also helps to increase the overall efficiency of the system.

2. Improved Product Quality: As we have used different IOT sensors to keep food products in the proper temperature so the overall quality of the food products is improved.

3. Enhanced Traceability and Transparency: Blockchain technology enhances the traceability and transparency of the cold chain. Reusable records of product movement allow stakeholders to follow perishable commodities from farm to fork. By facilitating targeted recalls in the event of quality issues or contamination occurrences, transparent traceability promotes both food safety and consumer confidence.

4. Optimal Resource Utilization: Internet of Things-based optimization techniques maintain the sustainability of the cold chain. Controlling temperature settings, route planning, and storage conditions aids in waste reduction, energy efficiency optimization, and environmental sustainability enhancement for all involved parties. This method supports CSR objectives and gradually reduces ongoing operating expenses.

5. Regulation Compliance: IoT solutions can assist in making sure that food safety and cold chain management laws, as well as relevant quality standards, are met. When accurate temperature monitoring, documentation, and transparent traceability are combined, regulatory compliance is guaranteed and the risks of non-operation are reduced.

6. Cost savings: Through waste minimization, product loss maximization, and operational process optimization, stakeholders gradually witness significant cost reductions. Better-quality products require fewer markdowns and discounts, while increased efficiency reduces operational expenses. Reduced maintenance costs and downtime are also a result of proactive maintenance and effective resource management.

7. Competitive Advantage: Not many business and industries are working on it and also it is required in today's world. People are now concerned about h=their health so they like to eat fresh food items so overall there is competitive advantage..

Model Images:

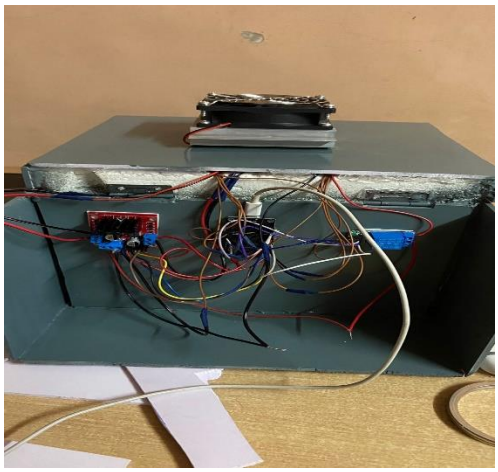

Fig. model image(a)

Fig. model image(b)

Conclusion:

In summary, the perishable food industry has a great deal of opportunities to use Internet of Things (IoT) technology to raise the standard and efficiency of cold chain logistics. IoT-driven systems, which offer several advantages such automation, data analytics, real-time monitoring, and enhanced traceability, are typically used to streamline cold chain operations.
Internet of Things (IoT) sensors continuously monitor environmental variables such as temperature, humidity, and cold chain position, enabling concerned parties to proactively identify and address any issues before they worsen. By obtaining important data on temperature fluctuations, inventory levels, and shipping routes, stakeholders may enhance cold chain operations and make informed decisions with the help of predictive analytics algorithms.

Automation is essential for avoiding errors, cutting down on manual involvement, assuring consistent product quality, and optimizing cold chain logistics processes. In order to maximize resource utilization, minimize waste, and enhance operational efficiency, stakeholders can implement automated temperature control mechanisms, inventory management systems, and routing algorithms.

Through the ability to track perishable goods from farm to fork and verify their origin and quality, blockchain technology improves traceability and transparency in the cold chain. Blockchain-based technologies enable immutable records of product movement and transactions, speeding up recalls and ensuring food safety.
All things considered, the introduction of IoT technologies in cold chain logistics has enabled the perishable food industry to make enormous strides toward improving quality, sustainability, and productivity. By using IoT-driven solutions, stakeholders may minimize waste, promote environmental sustainability, improve product quality assurance, and protect the integrity and safety of perishable food commodities across the supply chain.
However, problems with data security, interoperability, and scalability need to be fixed before IoT can be employed in cold chain logistics. To address these challenges and promote additional innovation in the sector, stakeholders must cooperate, standardize procedures, and continue their R&D.
Lastly, the application of IoT offers a ground-breaking chance to enhance cold chain logistics, ensuring the efficient and secure delivery of perishable food items to clients while meeting the demands of a global food supply chain that is continuously evolving.

Prospects:

When it comes to enhancing the quality and effectiveness of the cold chain for perishable food prepared using IoT, there is a great deal of space for future development and application. Among the outcomes that could occur are:
Better Technology for IoT Sensors: More advanced sensors that can track a greater variety of characteristics, like humidity, air quality, and light exposure, may become available as IoT sensor technology develops. This would improve the efficiency of the cold chain and give a deeper understanding of the storage conditions.

AI and ML Integration: By combining IoT data with AI and ML techniques, predictive analytics will be able to identify possible problems in the cold chain before they arise. Massive volumes of data can be analyzed by artificial intelligence to
By increasing the use of blockchain technology to improve traceability in the cold chain, it will be possible to obtain transparent and unalterable records of food origin, handling, and quality all the way down the supply chain. As a result, recalls pertaining to contamination or quality problems can happen more quickly and precisely, and stakeholders and customers might feel more trusted.

Automation and robots: These two elements improve cold chain operations by streamlining procedures including inventory control, loading and unloading, and temperature control. Automatic
IoT-enabled Packaging: Real-time monitoring of individual food packages within the cold chain can be achieved through the development of smart packaging systems integrated with IoT sensors. From manufacturing to consumption, the product's quality and safety are guaranteed by these intelligent packaging solutions, which are able to monitor changes in temperature and other environmental conditions. Data Analytics for Supply Chain Optimization: Production facilities, distribution hubs, retail locations, and the full cold chain network may all be optimized by utilizing big data analytics and predictive modeling. Supply chain stakeholders can find possibilities for process improvement, resource optimization, and cost reduction by evaluating historical data and real-time insights.

Sustainability and Environmental Monitoring: Internet of Things (IoT) technologies may be used to track energy usage, carbon emissions, waste production, and other environmental impacts of cold chain processes. Without compromising productivity or quality, the cold chain can reduce its environmental effect by using sustainable practices and resource efficiency.
International Standards and Cooperation: With the use of the Internet of Things, industry associations, governments, and other interested parties can collaborate to develop international standards and best practices for cold chain management. This would promote data interchange, interoperability, and uniformity in implementation, which would enhance the supply chain's efficacy and consistency.

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