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DEVELOPMENT OF INTELLIGENT DAIRY HYGIENE MONITORING SYSTEM

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ABSTRACT:

The dairy sector plays a critical role in the global food supply, but it faces significant challenges related to energy consumption, sanitation, and packaging waste. Milk has a limited shelf life, and quality control is essential throughout the milk processing chain, from collection on farms to processing and final products.

To meet regulatory and consumer demands for food safety and quality, various chemical and microbial tests are conducted. While hazard analysis testing is crucial, some tests may be redundant, highlighting the need to optimize quality control processes. The dairy sector's approach to Industry 4.0 entails proactive maintenance, production optimization, and logistical improvement.

Robotic milking machines, automated processing and packing lines, sensors for quick chemical and microbiological detection, and improved real-time data management are all part of this. By 2025, the dairy sector is projected to grow by 1.8% yearly and produce 177 million tons of milk. Advanced sensors on smart dairy management systems allow for quick data collection from storage and processing tanks for milk. After gathering the information, it is processed to help in decision-making. Scalability is a crucial component of IoT-enabled dairy management solutions that optimizes plant productivity and boosts revenues. These systems integrate intricate procedures for managing historical data through data loggers enabling thorough analysis of the dairy sector. The sensed data is sent to the cloud server for data processing, data storage and visualization through IoT PC interface from which the dashboard can be accessed by admin and the configured alerts through telegram bot and SMS to the subscribed account. This helps analyze the dairy business with a broader perspective, including detailed information about the plant processing, asset workings in terms of energy consumption, tank monitoring reports by monitoring hygiene and other miscellaneous managerial tasks such RFID enabled package tracking and collection from consumers. This synergy empowers IoT applications with seamless connectivity, scalability, and remote management.

KEYWORDS:

IoT, Energy Consumption, Hygiene Monitoring, Package Waste Collection NODE-RED, AWS.

1. INTRODUCTION:

According to the milking automation market in India, with a market value of USD 1,030 million in 2022, the milking automation market is projected to develop at a compound yearly growth rate of 7.20% from 2022 to 2030, when it is predicted to reach USD 1,796 million. The food item that is most commonly consumed in India is milk. Furthermore, with more than 20% of the world's production, it is the

biggest producer of this commodity. The nation produced 210 million tons of milk in 2022, nearly twice as much as it did in 2011.

Since milk has a short shelf life, strict quality control is required at every stage of the processing process, from farm collection to the end product's processing.

Numerous chemical and microbiological tests are carried out to guarantee food safety and satisfy consumer and regulatory requirements; however, some of these tests may be superfluous, indicating the need to improve quality control procedures. The dairy industry is improving its operations by adopting Industry 4.0 and optimizing production, improving logistics, and performing proactive maintenance. The implementation of automated processing and packing lines, robotic milking machines, and fast-responding sensors for microbiological and chemical detection are all parts of this shift, which is supported by sophisticated data management systems (Dadhaneeya et al., 2023). By 2025, the industry is projected to have grown by 1.8% yearly, generating over 177 million tonnes of milk. Modern sensors in intelligent dairy management systems, which enable quick data gathering from storage and processing tanks, are essential to this expansion. After being gathered and evaluated, this data helps in strategic decision-making. Since milk has a short shelf life, strict quality control is required at every stage of the processing process, from farm collection to the end product's processing. Numerous chemical and microbiological tests are carried out to guarantee food safety and satisfy consumer and regulatory requirements; however, some of these tests may be superfluous, indicating the need to improve quality control procedures. The dairy industry is improving its operations by adopting Industry 4.0 and optimizing production, improving logistics, and performing proactive maintenance. The implementation of automated processing and packing lines, robotic milking machines, and fast-responding sensors for microbiological and chemical detection are all parts of this shift, which is supported by sophisticated data management systems (Dadhaneeya et al., 2023). By 2025, the industry is projected to have grown by 1.8% yearly, generating over 177 million tonnes of milk. Modern sensors in intelligent dairy management systems, which enable quick data gathering from storage and processing tanks, are essential to this expansion. After being gathered and evaluated, this data helps in strategic decision-making.

2. BACKGROUND STUDY

The dairy industry faces critical challenges in optimizing energy consumption, maintaining stringent hygiene standards, and managing packaging waste effectively. To address these issues comprehensively, a one-stop solution integrating monitoring systems for dairy plant energy consumption, hygiene, and consumer packaging waste collection is essential. Globally, dairy plants account for a significant share of industrial energy usage, with recent statistics indicating an average consumption of 50-60 kWh per ton of milk processed. Concurrently, hygiene lapses in dairy production can lead to substantial economic losses, with reported incidents showing a 15% reduction in production efficiency. Packaging waste, a growing concern, sees consumers generating an estimated 5.2 million tons annually, emphasizing the urgency for efficient waste collection systems. As regulatory bodies tighten standards, the integration of real-time monitoring and smart solutions

becomes imperative for dairy plants seeking sustainable and compliant operations. Case studies reveal successful implementations of such integrated systems, highlighting their potential to revolutionize the dairy industry by enhancing energy efficiency, ensuring hygiene compliance, and streamlining packaging waste management.

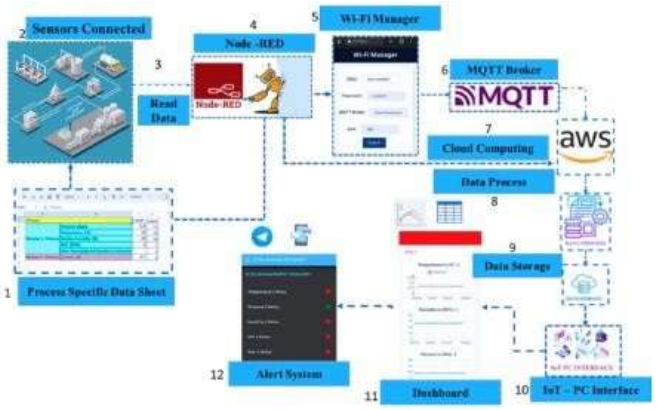
3. LITERATURE SURVEY:

The literature survey on "An IoT-enabled Comprehensive Solution for Monitoring Dairy Plants" delves into existing research related to IoT applications in dairy plant monitoring. It explores studies on sensor integration, data analytics, and real-time monitoring systems within dairy industry contexts. The survey aims to identify trends, challenges, and innovations in the implementation of IoT solutions, focusing on how they enhance operational efficiency, quality control, and resource management in dairy plants. By analyzing the current state of the literature, the survey provides a foundation for understanding the key components and advancements in IoT technology that contribute to comprehensive solutions for monitoring dairy plants. The literature review further investigates the practical implications and success stories of deploying IoT-enabled systems in dairy plants, shedding light on their impact on production processes, cost-effectiveness, and overall sustainability. It synthesizes findings from various sources to offer insights into the potential benefits, limitations, and areas for improvement in adopting IoT solutions for dairy plant monitoring. This survey serves as a valuable resource for researchers, practitioners, and stakeholders looking to comprehend the landscape of IoT applications in the dairy industry and pave the way for future developments.

4. OBJECTIVES:

- To create a unified platform for seamless integration of monitoring systems, providing holistic visibility and management of key operational aspects.
- To monitor and optimize dairy plant energy consumption in real-time to reduce costs and enhance efficiency.
- To ensure strict adherence to hygiene and protocols through continuous monitoring and user alerts.
- To track and manage package waste collection, implementing strategies to minimize waste and promote recycling.
- Facilitate easy documentation and reporting to ensure compliance with industry regulations and standards using data loggers.

5. METHODOLOGY:



Flow Diagram of the Proposed Work

This work outlines an inexpensive Internet of Things (IoT)-based system to lessen the loss of perishable items by

automatically monitoring real-time process parameter such as temperature, pressure, flow, level, gas as well as energy consumption. These current values are kept in Maria DB. Node-RED and the process-specific data from google sheets are combined, and data from AWS is 24 applied to the specific data. Additionally, a decision-supporting android app that analyses milk processing data at any time and from any location as well as predicts the status of the process efficiency based on measured in-the-moment characteristics. Work on the simulation is done with NodeJS, MySQL and Maria DB (Yangui, 2020). A sensing module, wireless connection technology, and status monitoring comprise the proposed system. In the block diagram, the prediction module and the web application module are depicted in figure 3.2. To guarantee the smooth operation of the suggested WSN of dairy plant, these modules communicate wirelessly with AWS. Sensors, a microcontroller, and a power supply PCB make up the WSN sensing module. The sensing module guarantees the cloud's real-time environmental data transmission from hardware. The real-time gauge information is kept in Maria DB. On cloud and is exported as a JSON file for status prediction processing (Miao et al., 2019). The status prediction module follows and includes a decision-making prediction model. Employing real-time environmental parameters, exporting information about commodity status as a JSON file from MySQL is a database. It makes inferences and forecasts the status of the commodity. A staff member can use a web application to do real-time process monitoring in the dairy plant. A model (Google sheet), and a supervisor is also automatically alerted to dangerous levels of conditions in the process. This makes it feasible for technical officers (website or mobile application) to take the prompt, necessary steps required to efficiency of the process and to reduce the energy consumption in an efficient way. Application in the section for data loggers determine whether a process's value is within a limit or send an alert notification transmitted via the Telegram bot. The supervisor will receive an automatic notification in the event of an alarm. A resource for prompt, necessary action in the dashboard.

- Sensors

IoT-enabled monitoring systems in the dairy plant use sensors to measure andmanage numerous data. These sensors are capable of measuring temperature, pressure, flow, gas and level. A central platform receives the data collected, enabling real-time monitoring and control (Bovo et al., 2020). This helps prevent milk from spoiling and ensures quality by ensuring that the process are within safe temperature limits.

- Data loggers

Even if the internet connection is briefly disrupted, data loggers continue to gather temperature and other pertinent data. By doing this, data loss due to network outages is prevented. Data loggers enable tracking and assessing even in places with poor connection by storing data locally. Since data loggers routinely 25 measure temperature with outstanding reliability and precision, the data they record can be recognized. In order to assist operators in taking prompt corrective action, data loggers can be set up to come up with alerts when temperature thresholds are exceeded.

❖ MQTT Broker

With MQTT, devices (such as sensors and data recorders) can publish data to a central server (a broker) and other devices can subscribe to pertinent data. The system's load is decreased and network traffic is kept to a minimum thanks to this effective communication.

Because MQTT messages are brief and use little bandwidth, they are appropriate for situations when network resources are constrained. In rural or resource-limited places, this is especially helpful. MQTT's broker-based framework makes scaling up and down simple. The system is adaptable to changing monitoring requirements since additional sensors or data loggers can be included without interfering with the current setup. MQTT enables both data transmission and device remote control. In order to maintain ideal conditions in the dairy plant, administrators can send directives to alter parameters.

MQTT includes security features like encryption and username/password authentication to guarantee the confidentiality of important process data.

❖ Cloud Computing

IoT-enabled monitoring systems in the dairy plant division heavily rely on cloud computing. To improve data management, operational effectiveness, and overall food safety, these systems make use of cloud platforms. First off, cloud platforms offer trustworthy options for data management and storage. In order to provide transparency for regulatory reporting, analysis, and decision-making, temperature and environmental data received from sensors and data recorders can be safely saved in the cloud. This long-term holding makes it easier to analyze historical trends, which is essential for upholding standards of quality. Another benefit of cloud-based IoT platforms is that they allow for real-time monitoring and analysis. The cloud receives sensor data, which is then immediately analyzed for patterns and anomalies. Operators are empowered to take quick remedial action to stop spoilage and guarantee product quality according to this real-time knowledge (Miao et al., 2019). Scalability is yet another important benefit. Cloud computing easily manages the growing volume of data from a growing number of sensors as the process activities rise. Because of its scalability, substantial infrastructure updates are not necessary, saving money and resources. Modern corporate processes require remote accessibility.

Stakeholders can access monitoring data through cloud-based solutions from any location, facilitating decision-making and responsiveness. Additionally, cloud platforms combine data 26 from numerous sources to provide an in-depth analysis of milk processing conditions that aids in the making of well-informed decisions.

❖ Telegram bot

Operators and the monitoring system can communicate and be controlled invisibly thanks to these bots. Operators can get real-time updates and notifications about temperature changes along with other shifts in the milk processing unit. Operators can check the current state of sensors, demand historical data, and get prompt notifications if crucial thresholds are crossed using the bot's interface. Telegram bots also make it possible to control devices remotely.

Operators can use the bot to transmit commands to change settings, start processes like thawing, or even start alarms. With this degree of remote control, responsiveness is improved and on-site presence is no longer necessary. The

food business gains from fast communication, remote control, and effective management of dairy plant conditions through incorporating Telegram bots onto IoT monitoring systems, thus guaranteeing food quality and regulatory compliance.

❖ User Interface

Operators and stakeholders can efficiently interact with the system through UI. Users can view real-time information from instruments and data foresters, including temperature, humidity, and other environmental parameters, through a well-designed user interface. Operators can easily evaluate the cold warehouse

Conditions and spot any irregularities according to this visual representation. Additionally, user interfaces include data analysis capabilities that let users examine past trends, spot patterns, and come to wise decisions. Warnings and alerts are prominently featured to ensure prompt attention to urgent circumstances, like temperature changes that can impact the quality of food. Furthermore, user interfaces include control features that enable operators to change temperature settings, start maintenance procedures, and get remote status updates. The capacity to control devices remotely improves responsiveness and operational efficiency.

5.1 PROPOSED WORK :

The monitoring of milk or product processing in the dairy plant is essential since any lapse in monitoring parameters such as temperature, pressure, flow, level, gas results in a significant loss of pasteurization efficiency and the product quality. The suggested strategy demonstrates a sophisticated one stop solution for monitoring dairy plant and warning system that helps to decrease spoilage of milk , continuous energy consumption monitoring, eradicates the risk of contamination through monitoring plant hygiene and sanitation and the process hygiene, and an app integrated with dashboard to collect waste packages from the consumers . For the proposed module to function, we have designed computer programmers with prediction models.

1. Initialize Power on the module.

2. Set up WiFi Manager: Configure WiFi settings to create a connection with the network.

3. Check WiFi Status: If the WiFi connection is successfully enabled (status ==connected), proceed to the next step.

4. Call AWS Cloud Server: Establish a connection to the AWS to enable data storage transmission.

5. While WiFi is Connected: Read Sensor Data: Continuously collect data from the sensors (temperature, humidity, etc.).Create JSON Data: Format the collected sensor data into a JSON structure for transmission. Update Maria DB: Store the data in a Maria DB database hosted on the cloud.

6. Wi-Fi Connection Failure: Restart Module: In case of

In this section, we offer the findings and analysis of our ground-breaking Internet of Things (IoT) monitoring system created for monitoring dairy plant. The parameters monitored in diary plant such as energy consumption, hygiene monitoring and package waste collection from consumers. Used unique interface to retrieve the past data or stored data from AWS cloud server by using data loggers. To monitor hygiene we using google sheet as hygiene checklist which can be assessed by specific employee's to enter the monitored data in google sheets and it can be used for audit purposes and for documentation. Sensors are used to monitor dairy plant process to prevent from spoilage and detection of level and flow rate of milk to ensure efficient milk processing in a sustainable way.

Process monitoring sensors and the energy meter are connected to the hardware dairy plant model as shown and the live monitoring data are displayed in the HMI dashboard.

Figure 6.1.1.Energy Monitoring (During Milk Processing)

From the figure 6.1.1. we come to know the one stop solution in which real time energy consumption monitoring, data retrieval , hygiene and sanitation monitoring checklists and packaging waste collection from the consumer dashboard are displayed . In this we will discuss each webpage in detail.

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Figure 6.1.2. Energy Consumption Dashboard

Table 6.1. Energy Consumption Monitoring Data

As shown in figure 6.1.2. the real time energy consumption is monitored in terms of system voltage (V), system frequency (Hz), system total active energy (J), system current (A), system total reactive energy (J), system power factor (kW) and displayed in the dashboard and if there is fluctuations in the voltage or current the alert system will be triggered to avoid short circuiting and equipment damage (Shine et al., 2019). Using MQTT the monitored data are stored in the cloud server (AWS) for processing and can be downloaded for energy auditing and analysis. The recorded energy consumption of the total plant and the milk plant for a duration of 3 days is analysed in interpreted in table 6.1.

6.2 SIGNIFICANCE AND LIMITATIONS

The dairy industry will benefit greatly from the adoption of a single point of contact for tracking energy use in dairy plants, consumer packaging trash collection, and cleanliness. First of all, it makes a comprehensive approach to efficiency and sustainability possible. It permits real-time monitoring and optimization of energy consumption, which can result in significant financial savings and a smaller environmental effect. It guarantees product safety and quality through the integration of hygiene monitoring, which is essential for consumer trust and adherence to health requirements. In addition, overseeing the direct collection of packaging trash from customers helps to satisfy corporate social responsibility objectives, promote a circular economy, and solve environmental issues in addition to strengthening brand loyalty. This all-inclusive technology makes data-driven decisions easier and optimizes operations in several aspects at once.

Nevertheless, there are several restrictions associated with putting such a system into place. A thorough monitoring system's initial setup, integration, and upkeep can be expensive and logistically difficult, especially for smaller dairy operations with constrained resources. Moreover, handling enormous volumes of data is complicated and calls for sophisticated analytics skills in order to successfully extract meaningful insights. Careful attention must be paid to privacy and data security issues, particularly when handling consumer-related data in waste collection.

Furthermore, customer participation is crucial to the success of packaging trash collection programs and can be unpredictable due to a variety of reasons outside the dairy plant's control.

7. CONCLUSIONS:

The agricultural internet of things (IoT) market was estimated to be worth USD 13.61 billion in 2022 and is

expected to grow at a compound annual growth rate (CAGR) of 9.50% from 2023 to 2032, reaching a value of approximately USD33.57 billion. Modern solutions with sophisticated sensor devices, gateway

Connectivity, and an integrated dashboard are offered by this one-stop shop. It provides the necessary scalability, flexibility in operation, and customization in accordance with business objectives for managers and other users. The solution has a real-time tracking system that fulfils the need to monitor the milk levels closely because too much spillage could result in waste.

Historical data management, which facilitates effective decision-making and corporate expansion, is another aspect that contributes significantly to the success of this one-stop shop solution. It facilitates the analysis of the business process's weaknesses and strengths, which aids in appropriate planning for overcoming obstacles. Advanced sensors in a smart dairy management system instantaneously gather data from the milk storage tank and transform it into a format that is easy to use so that business choices can be made with confidence. To summarize, the creation and application of an integrated Internet of Things (IoT) monitoring system holds great potential for enhancing productivity, sustainability, and quality of output in dairy operations. By combining MKconsumer packaging trash collection, hygienic and sanitation inspections, and real-time energy usage

monitoring onto a single platform, this approach enables comprehensive control and improvement of dairy operations. Despite the initial launch costs and logistical challenges, the benefits include les environmental impact, enhanced brand loyalty, and financial savings. However, ongoing attention to data security, analytical capabilities, and user interaction is still required for successful adoption and long-term survival. As the dairy industry grows, it is anticipated that the application of such state-of-the-art monitoring systems will be critical to promoting innovation and meeting new customer demands (Alonso, 2020).

By accurately tracking energy usage, dairy operations can identify areas for improvement, leading to reduced operational costs and a lower carbon footprint.

IoT devices can monitor hygiene in real-time, ensuring products meet health standards and reducing the risk of contamination. Additionally, monitoring packaging waste can lead to more sustainable practices, including recycling and reducing waste. Overall, such an approach can improve productivity, ensure product quality, and contribute to environmental conservation.

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