

EggSense: Smart Egg Health and Quality Monitoring System Development for Health Applications

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Abstract—This paper presents EggSense, an IoT-based system for real-time monitoring of egg quality and health. Using an Arduino/ESP32 platform and Blynk, EggSense integrates infrared (IR) LEDs to measure egg protein content and a camera module for image processing to detect diseases by identifying shell abnormalities.

The system provides real-time data visualization and alerts via a mobile interface, enabling remote monitoring. EggSense offers a non-invasive, efficient solution for improving egg quality control in the poultry industry.

This paper discusses the design, implementation, and potential benefits of the systems. This paper introduces EggSense, an innovative IoT-based system designed for the real-time monitoring of egg quality and health in the poultry industry. The system is built on an Arduino/ESP32 platform, utilizing Blynk for mobile connectivity, and integrates several advanced components to ensure comprehensive monitoring.

EggSense employs infrared (IR) LEDs to assess the protein content within eggs, providing crucial insights into their nutritional value. In addition, the system is equipped with a camera module capable of performing image processing to detect diseases or irregularities by identifying abnormalities in the eggshells. This combination of sensor-based data collection and image analysis ensures that egg quality is monitored non-invasively, with real-time updates accessible via a mobile interface.

The system offers several advantages, particularly in its ability to provide real-time data visualization and immediate alerts, allowing for remote monitoring and swift intervention when issues arise.

This capability enhances the efficiency and accuracy of quality control processes in the poultry sector, reducing reliance on manual inspection and enabling producers to address problems early.

The paper explores the complete design and implementation of the EggSense system, discussing its hardware and software components, data processing techniques, and integration with mobile platforms.

Furthermore, it highlights the potential benefits of adopting EggSense, such as improved egg quality, better disease management, and increased operational efficiency, making it a valuable tool for modern poultry farms.

Keywords— EggSense, IoT-based system, real-time monitoring, egg quality, egg health, Arduino, ESP32, Blynk, infrared LEDs, egg protein content, camera module, image processing, disease detection, shell abnormalities, non-invasive monitoring, data visualization, mobile interface, remote monitoring, poultry industry, quality control, hardware, software, data processing, mobile platforms, disease management, operational efficiency, poultry farms, Egg quality monitoring, IoT, Arduino, ESP32 Blynk, infrared LED, camera module, image processing, protein content, disease detection.

I. INTRODUCTION

The poultry industry is crucial for global food production, providing billions of eggs annually. Ensuring egg quality and safety is essential for both producers and consumers. Traditionally, egg quality has been monitored using manual methods like candling, which involves inspecting eggs with a light source to detect defects or irregularities. However, these methods are labor-intensive, time-consuming, and prone to human error, making them impractical for large-scale operations. Additionally, they lack continuous or real-time data, which limits their effectiveness in modern, high-demand poultry farming. As food safety standards tighten and the demand for high-quality eggs grows, the need for automated and more reliable monitoring systems has become evident. In addition to industrial concerns, consumers at the household level are also becoming increasingly aware of food quality, particularly in relation to freshness and potential health risks. This has generated a growing interest in technologies that can ensure the safety and quality of eggs in both professional and domestic settings [1].

Recent advancements in the Internet of Things (IoT) have opened the door to new possibilities for creating smart, automated systems capable of performing complex monitoring tasks with minimal human intervention. IoT-based systems can gather and analyze data in real-time, allowing for remote access and automated decision-making, which enhances the efficiency and accuracy of egg quality control processes. We introduce EggSense, a comprehensive IoT-based solution for real-time egg quality and health monitoring. EggSense integrates an Arduino / ESP32 microcontroller with a variety of sensors and image processing technologies to non-invasively assess two critical aspects of egg quality: protein content and potential diseases. The system utilizes infrared (IR) LEDs to measure the attenuation of light passing through the egg, which provides insights into the protein concentration, a key indicator of nutritional value. Simultaneously, a camera module captures high-resolution images of the egg shell, which are analyzed through image processing algorithms to detect potential diseases or structural abnormalities such as cracks, deformities, or irregularities in the shell [2].

What sets EggSense apart is its versatility. In commercial poultry farms, the system can be deployed for continuous, automated monitoring, allowing for early detection of substandard eggs and enabling farm operators to improve efficiency and reduce losses. In household settings, EggSense offers a user-friendly solution for monitoring the freshness and quality of eggs, providing peace of mind to consumers who want to ensure the safety of their food. The system's ability to connect to the Blynk IoT platform allows for real-time data visualization and alerts, delivered directly to a mobile interface and enabling remote monitoring. The system offers several advantages, particularly in its ability to provide real-time data visualization and immediate alerts, allowing for remote monitoring and swift intervention when issues arise. This capability enhances the efficiency and accuracy of quality control processes in the poultry sector, reducing reliance on manual inspection and enabling producers to address problems early. The paper explores the complete design and implementation of the EggSense system, discussing its hardware and software components, data processing techniques, and integration with mobile platforms. Furthermore, it highlights the potential benefits of adopting EggSense, such as improved egg quality, better disease management, and increased operational efficiency, making it a valuable tool for modern poultry farms [3].

II. LITERATURE SURVEY

The development of IoT-based systems for real-time monitoring and quality control in agricultural and food industries has been a growing area of research. Various systems have been designed to monitor environmental conditions, improve yield, and ensure product quality. This literature survey reviews key research and technological advancements related to IoT-based monitoring systems, particularly in the context of poultry and egg quality control, to provide a foundation for the development of EggSense [4].

IoT in Agriculture and Poultry Industry: Numerous studies have explored the application of IoT in agricultural practices to enhance productivity and streamline operations. Devices such as sensors and cameras are commonly used to monitor environmental parameters like temperature, humidity, and livestock health. For instance, Guo et.al. (2019) developed an IoT-based poultry monitoring system to assess the environmental factors in chicken

farms, helping farmers optimize feeding and living conditions for livestock. Similarly, Satija et.al. (2018) demonstrated the integration of sensors to monitor animal health and detect abnormal behavior in real-time. These studies highlight the role of IoT in automating processes and improving animal health management. However, limited attention has been given to the application of these technologies for monitoring egg quality directly, underscoring the need for focused research in this domain [5].

Egg Quality Monitoring Techniques: Traditional methods for egg quality assessment rely heavily on manual inspection and laboratory tests, which are time-consuming and often invasive. In contrast, non-invasive techniques using optical and imaging technologies have gained interest. Gharib et.al. (2020) proposed a vision-based system for automatic egg grading, utilizing image processing algorithms to assess shell characteristics. Moreover, infrared spectroscopy has been explored for its potential in non-invasively measuring internal egg quality, such as yolk and albumen content (Rodríguez-Pulido et.al., 2016).

These technologies offer faster, more efficient ways to monitor eggs, but their integration into an IoT-based system remains underdeveloped, particularly in combining multiple sensing techniques for comprehensive quality analysis [6].

Infrared (IR) Sensing and Image Processing in Egg Monitoring: Infrared (IR) sensing has proven effective in detecting internal characteristics in eggs without damaging the shell. Studies by Yang et.al. (2017) used near-infrared spectroscopy to determine the freshness of eggs by analyzing albumen and yolk quality. Additionally, machine learning models have been applied to classify eggs based on shell characteristics (Wang et.al., 2018). Image processing techniques, combined with optical sensors, have also been used to detect abnormalities on the eggshell, identifying defects or diseases that affect the overall quality of the egg. These advancements serve as a foundation for EggSense, which integrates both IR sensors and image processing for real-time, non-invasive egg monitoring [7].

IoT Platforms for Remote Monitoring: IoT platforms like Blynk have been widely adopted for remote monitoring and control in various applications. Wu et.al. (2020) demonstrated the use of Blynk in a smart irrigation system that allowed farmers to remotely monitor and control water distribution. Blynk's real-time data visualization and mobile alerts have been shown to significantly enhance operational efficiency.

This capability can be translated to the poultry industry, where remote monitoring of egg quality through mobile applications can reduce the need for manual intervention and provide farmers with timely information about egg health [8].

Challenges and Opportunities in Poultry Industry IoT Applications: While IoT technology has revolutionized the agriculture and poultry sectors, challenges remain, particularly in cost, system complexity, and data accuracy. Integrating multiple sensors and maintaining real-time communication can introduce technical hurdles. Moreover, IoT adoption in rural and small-scale poultry farms is still limited by factors such as infrastructure and initial investment. Nonetheless, studies like that of Kumar et.al. (2019) emphasize the potential for IoT systems to improve productivity, reduce waste, and enhance food safety. These insights suggest that developing a cost-effective and efficient system like EggSense can address many of these challenges, especially for small and medium-scale poultry operations [9].

In a nutshell, while significant advancements have been made in IoT-based monitoring systems for agriculture and animal health, the application of these technologies to egg quality monitoring is still in its infancy. The existing body of literature provides valuable insights into the use of non-invasive sensing techniques and real-time monitoring systems, which EggSense seeks to combine and optimize for egg health and quality monitoring applications [10].

III. PROPOSED METHODOLOGY

In this section, the proposed methodology is presented in brief. The system overview is presented here in this paragraph. The proposed EggSense system employs the ESP32 microcontroller and an integrated camera module to monitor egg quality and health through real-time image processing and IoT technology. The system aims to assess protein content and detect potential diseases by analyzing images of eggs, providing users with actionable insights via an IoT platform.

A. Hardware Configuration

The hardware configuration involves the following key components as follows.

- **Microcontroller Unit (MCU):** The system is built on an Arduino/ESP32 platform, which serves as the central processing unit for handling sensor inputs, data processing, and communication tasks. The ESP32 provides integrated Wi-Fi and Bluetooth capabilities, essential for IoT applications.

- **Infrared (IR) LED Sensors:** The system includes multiple IR LEDs, which are used to measure the protein content inside the eggs. These sensors provide non-invasive measurements by sending infrared light through the eggshell and analyzing the reflection or transmission data.
- **Camera Module:** An image processing camera is integrated into the system to capture high-resolution images of the eggshell. The camera helps detect abnormalities or defects on the shell's surface that could indicate health issues or quality problems.
- **Power Supply:** The system operates with a standard 5V power supply to ensure stable operation of the microcontroller and sensors. A battery backup may be included for uninterrupted performance during power fluctuations.
- **Blynk Integration:** To provide real-time monitoring and user interface, the hardware is connected to the Blynk IoT platform, allowing data visualization, alerts, and remote access via a mobile application.
- **Communication Module:** The Wi-Fi/Bluetooth communication module integrated into the ESP32 facilitates wireless data transfer to the cloud, enabling remote monitoring and control of the system from a mobile device.

This hardware configuration ensures efficient, non-invasive monitoring of egg health and quality, making it suitable for real-time applications in the poultry industry.

B. Microcontroller

- **ESP32:**
Selected for its dual-core processor, ample memory, and built-in Wi-Fi and Bluetooth capabilities, facilitating both image processing and data transmission.
- **Arduino Uno:**
Although the Arduino Uno is less powerful compared to the ESP32, it may be used in conjunction with the ESP32 for simpler tasks or as a supplementary component in the system. The Arduino Uno is well-suited for basic sensor interfacing and control tasks but lacks the capability to handle advanced image processing. It can be employed to manage IR LEDs for protein content measurement or to interface with additional sensors if needed.

C. Camera Module

- Captures high-resolution images and interfaces seamlessly with the ESP32 for efficient data handling and processing.

D. Infrared (IR) LEDs and Sensors

- **IR LEDs:** Three IR LEDs are used to measure the protein content of eggs. These LEDs emit infrared light that passes through the egg. By analyzing the attenuation of this light, the system estimates the protein concentration.
- **IR Sensors:** Complementing the IR LEDs, IR photodiodes or phototransistors are used to receive the transmitted infrared light. These sensors measure the amount of IR light that passes through or is reflected by the egg. The data collected by the IR sensors are used to calculate the protein content based on the attenuation of the light.
- **Environmental Sensors:** Temperature and humidity sensors are integrated to monitor the storage conditions of the eggs. These sensors provide additional data that can enhance the accuracy of the quality assessment by considering environmental factors.

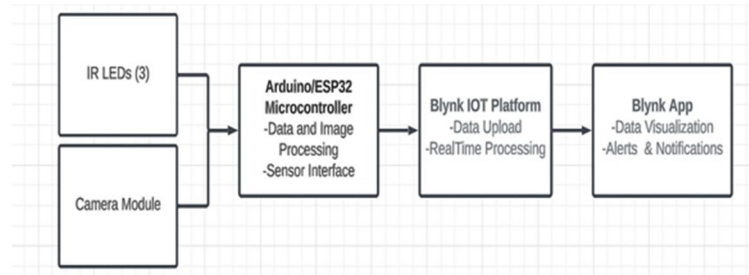
IV. SOFTWARE & DATA INTEGRATION

- **Image Processing:** The system processes images to detect external and internal defects in eggs. This involves using algorithms to analyze visual data and identify abnormalities.
- **Blynk Platform:** Blynk is used to facilitate real-time data transmission and visualization. The Blynk app integrates with the ESP32 microcontroller to display real-time information on egg quality, including protein content and image analysis results. It provides a user-friendly interface for monitoring and alerts, ensuring that users receive timely updates and can take necessary actions based on the data.

V. CALIBRATION & TESTING

- **Calibration:** Adjust the system for accurate measurements by testing with various egg samples.
- **Performance Evaluation:** Assess the system's accuracy, reliability, and response time.

The Fig. 1 shows the block diagram of the proposed system where the different types of sensors are being integrated to form the overall system.



VI. EXAMINATION OF MANY PAPERS

S.B. Santoso et.al. (2020) developed a Smart Chicken Eggs Incubator that employs IoT technologies to enhance egg hatching processes by automating environmental monitoring [1]. Their system integrates embedded hardware, a web-based application, and a Telegram bot to provide real-time updates on temperature, humidity, and egg status, along with notifications for any parameter deviations. The web application, designed using Object-Oriented Analysis and Design (OOAD) methods, ensures a modular and user-friendly interface for monitoring sensor data. Prototype testing over 21 days with 3,402 data entries confirmed the system's efficiency, with optimal data collection intervals of 9 to 10 minutes. These findings demonstrate the effectiveness of IoT-based monitoring and real-time notifications, which directly support the objectives of EggSense by emphasizing the value of integrating similar technologies for real-time egg quality assessment and management.

Maheesa, A. Putrada, and M. Abdurrohman et.al. (2019) developed an egg quality detection system that utilizes fuzzy logic combined with sensor data to improve accuracy in determining egg quality [2]. Traditional methods involve using a flashlight to inspect eggs, but this system integrates light and weight sensors with a microcontroller to assess egg quality. The fuzzy logic approach processes sensor data to differentiate between good and rotten eggs, with Firebase used for real-time data storage. The system demonstrated a 95% accuracy rate in detecting egg quality from a sample of 20 eggs, significantly outperforming a non-fuzzy logic system, which achieved only 75% accuracy. This enhancement in detection accuracy, achieved by optimizing the system with fuzzy logic, underscores the effectiveness of advanced data processing methods in improving quality assessments.

Alvin S. Alon et.al. (2019) proposed an image processing approach for inspecting and grading egg quality, addressing the inefficiencies of manual inspection methods [3]. Their system utilizes non-destructive and cost-effective image processing techniques to detect defects such as cracks, dirt, and other quality issues. The approach demonstrated high effectiveness, achieving a 91.33% accuracy rate for identifying high-quality eggs and detecting external cracks or dirt. For internal egg inspection, the system achieved 100% detection of the yolk, showcasing its capability to thoroughly assess both external and internal egg conditions. The use of algorithms like blurring and Canny edge detection contributed to the system's performance, providing reliable results in egg quality assessment. These findings are relevant to the EggSense project, as they validate the effectiveness of image processing methods in detecting various egg quality issues, reinforcing the potential of integrating such techniques for comprehensive egg monitoring.

Moch. Kholil et.al. (2023) developed a system for detecting egg conditions using Pixycam, a tool that integrates with Arduino for image processing [4]. Their approach leverages computer vision to replace manual egg inspection, traditionally done by soaking eggs or using strong light to check internal and external conditions. By utilizing Pixycam for shell-color filtering, the system achieved a 100% success rate in distinguishing between fresh and rotten eggs from a sample of 100 eggs (70 fresh and 30 rotten). This demonstrates the effectiveness of using computer vision and specialized hardware like Pixycam for accurate and efficient egg quality assessment. The successful application of these technologies supports the implementation of similar methods in EggSense, aiming to enhance accuracy and reduce manual inspection errors in egg quality monitoring.

W. Fang et.al. (2013) investigated a method for detecting cracks in preserved eggs using polarized light [5]. Their approach involved illuminating the eggs with a sodium lamp and capturing polarization images through a Polarization Optical System. By calculating and fusing Stokes and polarization images, the researchers were able to significantly enhance contrast and filter out background scattering light. This polarization imaging technique demonstrated increased detection and discrimination efficiency for identifying eggshell cracks. The results highlight the potential for advanced imaging techniques to improve the accuracy of defect detection in eggs.

Integrating similar polarized light imaging methods into EggSense could further enhance the system's capability to detect subtle cracks and defects, contributing to more precise egg quality assessment.

De Ketelaere et.al. (2004) explored various modern sensor technologies for non-destructive measurement of egg quality, addressing the limitations of traditional human inspection methods such as candling [6]. The study highlights the advancement of sensors capable of assessing both external and internal egg quality at high throughput rates. The sensors are categorized into three main types: mechanical sensors for physical shell quality assessment, spectroscopic sensors for internal quality analysis, and computer vision systems that emulate human visual inspection. The paper emphasizes that these modern technologies, including ultrasonic, magnetic resonance, and electronic nose sensors, are increasingly replacing manual candling in egg grading systems. The insights from this research support the integration of advanced imaging and sensor technologies in EggSense, particularly in enhancing the accuracy and efficiency of egg quality evaluation by leveraging both external and internal quality assessment methods.

VII. CONCLUSIONS

The EggSense system marks a significant advancement in egg quality and health monitoring by integrating cutting-edge technologies, including image processing, infrared light attenuation measurements, and IoT capabilities. The ESP32 microcontroller plays a pivotal role, enabling efficient real-time processing and data transmission. This setup ensures that the system can provide accurate and timely information about egg quality. By using infrared LEDs and sensors, EggSense accurately measures protein content, offering valuable insights into egg quality. Furthermore, its image processing capabilities enhance disease detection by identifying physical abnormalities, thereby improving the overall effectiveness of the system. The IoT integration within EggSense facilitates seamless data transmission and visualization, allowing for practical remote monitoring. This functionality makes EggSense suitable for both commercial egg production and household use, demonstrating its versatility. Future enhancements may focus on refining image processing algorithms, expanding sensor integration, and improving user interface features to increase accuracy and usability. By continuously optimizing these aspects, EggSense has the potential to further enhance egg quality assessment, offering reliable and actionable insights that could transform practices across various settings.

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