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Detection of Pre-Spoiling Thermal Signatures in Stored Grain using a Low- Cost Embedded IoT Probe

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ABSTRACT: A significant contributor to post-harvest losses is grain rotting during storage, which is frequently linked to variations in internal temperature brought on by biological activity. Continuous temperature monitoring can offer helpful indicators of the development of rotting in stored grain, according to earlier research. This work presents a low-cost embedded Internet of Things (IoT) probe for tracking temperature changes in grain that has been stored. Over time, the system logs interior temperature data and examines anomalous temperature variations that might signal the beginning of spoiling. The suggested probe is easy to use, energy-efficient, and appropriate for use in grain storage settings. According to experimental findings, the technology can help detect spoilage related temperature fluctuations early on, which will help with better grain storage management.Keywords: grain storage Thermal monitoring; pre-spoilage detection IoT-based monitoring, temperature fluctuation, and embedded systems preventing post harvest losses; Low-cost sensing; spoiling grain in storage; Monitoring of agriculture

KEYWORDS: Pre-spoilage detection, Grain storage monitoring, Thermal signatures, Low-cost IoT probe, Embedded sensing system, Smart agriculture, Post-harvest management.

I. INTRODUCTION

Grain storage plays a critical role in ensuring food security and maintaining the quality of agricultural produce after harvest. However, improper storage conditions often lead to spoilage caused by microbial growth, moisture migration, and biological activity within the grain mass. These factors result in temperature variations that gradually degrade grain quality and cause significant post-harvest losses. Early identification of such changes is essential to enable timely preventive measures and reduce economic loss. Traditional methods of monitoring grain storage rely mainly on manual inspection or periodic measurement of environmental parameters. These approaches are often time-consuming, labor-intensive, and incapable of providing continuous information about the internal condition of stored grain. Moreover, visible signs of spoilage generally appear only after substantial damage has already occurred, limiting the effectiveness of corrective actions. In recent years, embedded systems and Internet of Things (IoT) technologies have been increasingly explored for agricultural monitoring applications. Temperature sensing, in particular, has been recognized as a reliable indicator of biological activity and spoilage development in stored grain. Continuous thermal monitoring

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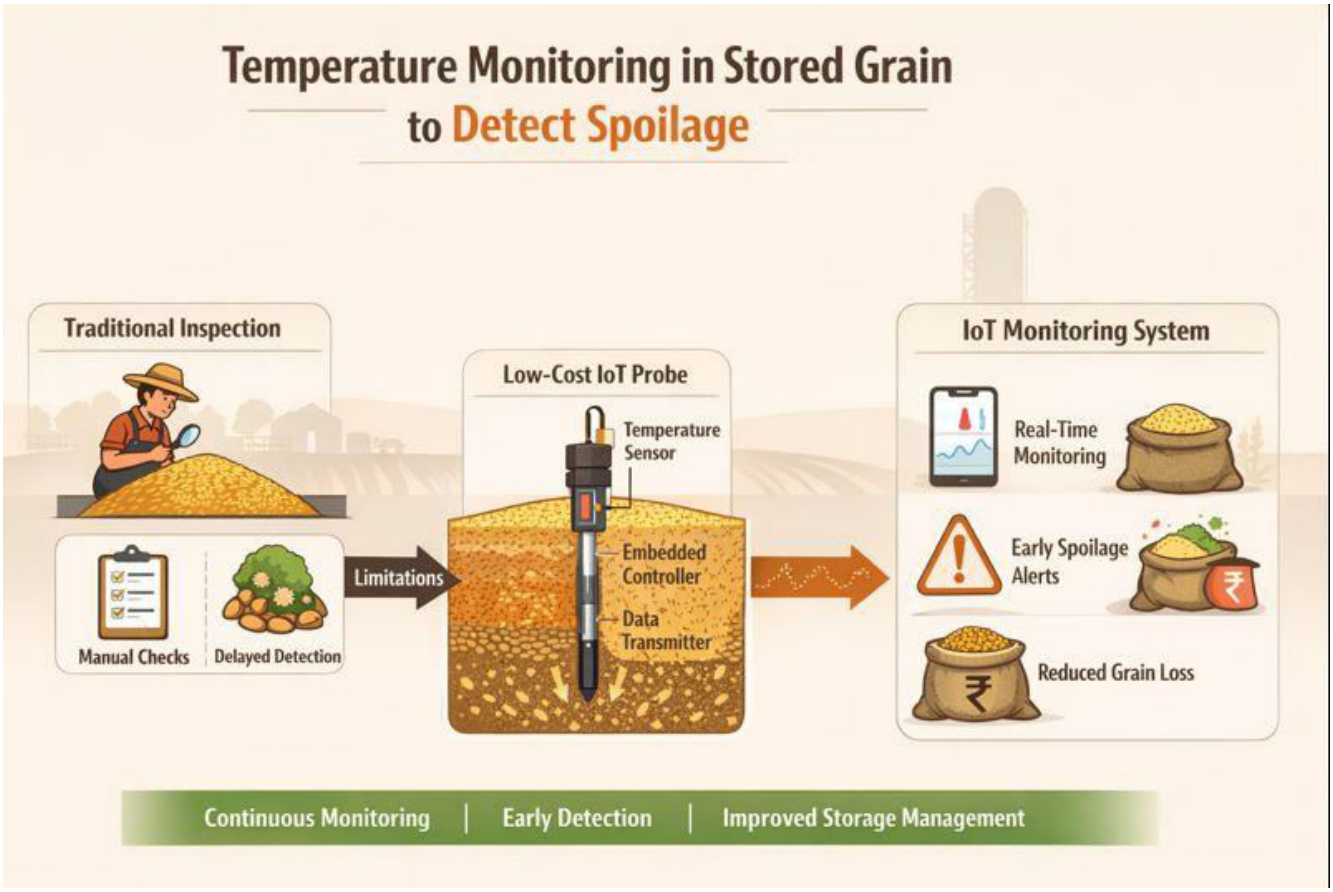
enables the observation of abnormal temperature changes that may signal the early stages of deterioration. However, many existing systems are expensive, complex, or unsuitable for deployment in small-scale storage facilities. This paper presents a low-cost embedded IoT-based probe designed for monitoring thermal variations in stored grain. The proposed system focuses on detecting abnormal temperature behavior that may indicate the onset of spoilage. The probe is compact, energy efficient, and easy to deploy, making it suitable for long-term grain storage environments. By providing continuous thermal data, the system supports improved storage management and contributes to the reduction of post-harvest grain losses



II. LITERATURE REVIEW

Effective monitoring of stored grain is crucial for minimizing post-harvest losses caused by microbial growth, insect infestation, and moisture migration during storage. Conventional methods such as periodic manual inspection and sampling often fail to detect internal spoilage at an early stage, particularly the self-heating phenomenon that develops inside bulk grain due to biological respiration. To overcome these limitations, several studies have investigated IoT-based grain storage monitoring systems that utilize temperature, humidity, and gas sensors for real-time data acquisition and remote supervision. Among these parameters, temperature has been widely recognized as a primary indicator of grain deterioration, as early spoilage is typically accompanied by localized thermal anomalies before visible damage occurs. Research involving sensor networks, embedded systems, and thermal analysis has demonstrated the effectiveness of temperature monitoring in identifying potential spoilage zones within storage structures. However, many existing approaches rely on expensive commercial sensor assemblies, complex installations, or are optimized for large-scale silos, limiting their applicability for low-cost and scalable deployment. Moreover, most reported systems focus on general environmental condition monitoring rather than the targeted detection of pre-spoiling thermal signatures. These gaps in existing literature highlight the necessity for a low-cost embedded IoT probe capable of detecting early thermal deviations in stored grain, enabling timely intervention and improved post-harvest management.

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III. PROBLEM STATEMENT

Stored grain spoilage often begins with internal self-heating caused by microbial and insect activity, which is difficult to detect using conventional manual inspection methods. Existing monitoring systems are either costly or focus only on general environmental conditions, making early detection of pre-spoiling thermal signatures unreliable. Therefore, there is a need for a low-cost embedded IoT-based probe that can continuously monitor internal grain temperature and detect early thermal anomalies to prevent spoilage and reduce post-harvest losses.

IV. METHODOLOGY

The proposed system employs a low-cost embedded IoT probe designed to monitor thermal variations within stored grain. Temperature sensors are strategically embedded at different depths of the grain mass to continuously measure internal temperature. The sensed data is collected by a microcontroller-based embedded unit, where it is processed to identify abnormal thermal deviations that indicate pre-spoiling conditions. The processed data is then transmitted wirelessly to a cloud or local monitoring platform using an IoT communication module. Threshold-based analysis is used to detect early thermal anomalies, and alerts are generated when temperature values exceed predefined safe limits. This enables real-time monitoring and early intervention to prevent grain spoilage while maintaining low system cost and energy efficiency.

V. OBJECTIVES

- To design and develop a low-cost embedded IoT probe for monitoring stored grain conditions.
- To continuously measure internal grain temperature for identifying early thermal changes.
- To detect pre-spoiling thermal signatures using threshold-based analysis.
- To enable real-time data transmission and remote monitoring through an IoT platform.
- To provide early alerts for timely intervention and reduction of post-harvest grain losses.

VI. WORKING

1. The low-cost embedded IoT probe is placed inside the stored grain at required depth levels.
2. Temperature sensors embedded in the probe continuously measure the internal temperature of the grain.
3. The sensed temperature data is sent to the microcontroller unit for processing.
4. The microcontroller compares the measured temperature values with predefined safe threshold limits.
5. If abnormal thermal variation is detected, it is identified as a pre-spoiling thermal signature.
6. The processed data is transmitted wirelessly using an IoT communication module.
7. The temperature data is displayed on a cloud or remote monitoring platform in real time.
8. When the temperature exceeds the threshold value, an alert notification is generated for the user.

ADVANTAGES

- Enables early detection of pre-spoiling thermal signatures in stored grain.
- Reduces post-harvest losses by allowing timely preventive action.
- Uses a low-cost embedded IoT probe, making the system affordable.
- Provides real-time monitoring and remote access to data.
- Simple design with low power consumption and easy deployment.
- Minimizes the need for manual inspection and human intervention.
- Suitable for small, medium, and large-scale grain storage facilities.

VII. FUTURE SCOPE

- Integration of humidity and gas sensors (CO_2 or NH_3) for more accurate spoilage detection.
- Application of machine learning algorithms to predict spoilage trends based on historical thermal data.
- Deployment of multiple IoT probes to enable spatial temperature mapping of large storage facilities.
- Development of a mobile application for real-time alerts and remote monitoring.
- Use of energy-efficient power sources such as solar energy to enhance system sustainability.
- Extension of the system for monitoring other agricultural products such as pulses and oilseeds.

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VIII. CONCLUSION

This work presents the design and implementation of a low-cost embedded IoT probe for detecting pre-spoiling thermal signatures in stored grain. The proposed system effectively monitors internal grain temperature and identifies early thermal anomalies associated with spoilage conditions. Real-time data transmission and alert mechanisms enable timely intervention, thereby reducing post-harvest losses and improving grain storage management. The system is cost-effective, easy to deploy, and suitable for various storage scales, making it a practical solution for enhancing food quality and storage safety. Overall, the proposed approach demonstrates significant potential for improving post-harvest grain preservation through smart monitoring technologies.

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