



Design and Fabrication of Smart Grain Storage and Spoilage Detection System

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How to Cite this Article:

Fulzele, A. A., Badge, A. G., Sarkar, A. B., Kurhade, K. & Shende, G. A. (2026). Design and Fabrication of Smart Grain Storage and Spoilage Detection System. International Journal of Creative and Open Research in Engineering and Management, <i>02</i>(9), 1-9. <https://doi.org/10.55041/ijcope.v2i9.206>

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<https://doi.org/10.55041/ijcope.v2i9.206>

Abstract— Grain storage is an important part of the agricultural supply chain because improper environmental conditions can reduce grain quality and increase the possibility of deterioration. Conventional storage monitoring often depends on periodic manual inspection, which may not provide continuous information about changes in temperature, humidity, and air quality. This paper presents a **Smart Grain Storage and Spoilage Detection System** that continuously monitors important storage parameters and Temperature and humidity are important parameters in storage monitoring. Excessive humidity may indicate an unfavourable moisture condition, while changes in temperature can indicate changes in the storage environment. Gas or air-quality variation can provide additional information about environmental changes occurring inside a storage area.

Traditional grain-storage practices may depend on periodic manual inspection [1]. Such inspection can identify visible problems but may not detect sudden environmental changes between inspection periods. In addition, manual monitoring generally does not provide a continuous historical record of sensor measurements.

provides the information through a web-based dashboard. A DHT11 sensor is used to measure temperature and humidity, while an MQ-135 sensor is used to monitor gas or air-quality variation. A microcontroller or processing unit collects the sensor measurements and evaluates them using predefined threshold conditions. Based on the sensor values, the system classifies the storage condition into **SAFE, WARNING, or SPOILAGE RISK**. The web dashboard provides real-time sensor values, visual progress indicators, sensor history graphs, system status, and alert messages. The proposed system provides a simple and low-cost approach for continuous environmental monitoring and early identification of potentially unfavourable grain-storage conditions.

I. INTRODUCTION

Grain storage is essential for preserving harvested agricultural products until they are processed, transported, or consumed [1], [4]. During storage, environmental conditions can change due to temperature variation, moisture, ventilation, weather, and other factors. Continuous observation of the storage environment can help identify such changes at an early stage.

Keywords— Grain storage, spoilage detection, IoT, DHT11, MQ-135, temperature monitoring, humidity monitoring, web dashboard, environmental monitoring

Internet of Things (IoT)-based monitoring provides an alternative approach by connecting sensors to a processing unit and a digital monitoring interface [3], [5]. Sensor information can be collected automatically and displayed to users through a web dashboard. Such an approach can reduce dependence on continuous physical inspection and provide a convenient method for observing storage conditions.

This paper proposes a **Smart Grain Storage and Spoilage Detection System** using DHT11 and MQ-135 sensors. The DHT11 provides temperature and humidity measurements, while the MQ-135 provides a gas/air-quality indication. The collected information is processed using predefined threshold



conditions and classified into three status levels: SAFE, WARNING, and SPOILAGE RISK.

The major objectives of the proposed system are:

1. To continuously monitor temperature and humidity.
2. To monitor gas/air-quality variation.
3. To evaluate sensor measurements using predefined thresholds.
4. To classify storage conditions into three status categories.
5. To display real-time sensor information through a web dashboard.
6. To maintain historical sensor information.
7. To provide visual warnings when unfavourable conditions are detected.

II. PROBLEM STATEMENT AND PROPOSED SOLUTION

A. Problem Statement

Conventional grain-storage monitoring can have several limitations [1], [4]. Periodic manual inspection may result in delayed detection of changing environmental conditions. It can also be difficult to identify sudden variations in temperature, humidity, or air quality without continuous measurement.

The major problems addressed by the proposed system are:

- Delayed identification of unfavourable storage conditions.
- Lack of continuous temperature monitoring.
- Lack of continuous humidity monitoring.
- Limited monitoring of air-quality/gas variation.
- Lack of historical sensor information.
- Difficulty identifying sudden environmental changes.
- Dependence on manual inspection.

B. Proposed Solution

The proposed system continuously collects sensor information and presents it through a web dashboard. The DHT11 sensor measures temperature and humidity, while the MQ-135 sensor monitors gas/air-quality variation.

The ESP-12E module evaluates the sensor measurements against configurable threshold values. The result is converted into an easy-to-understand status:

SAFE: All monitored parameters are within the configured acceptable range.

WARNING: One or more monitored parameters require attention.

SPOILAGE RISK: One or more parameters have reached a configured critical condition.

The system therefore provides an environmental risk indication rather than claiming to directly diagnose grain spoilage.

III. SYSTEM ARCHITECTURE

The proposed architecture consists of sensing, processing, communication, and visualization components, as shown in Fig. 1.

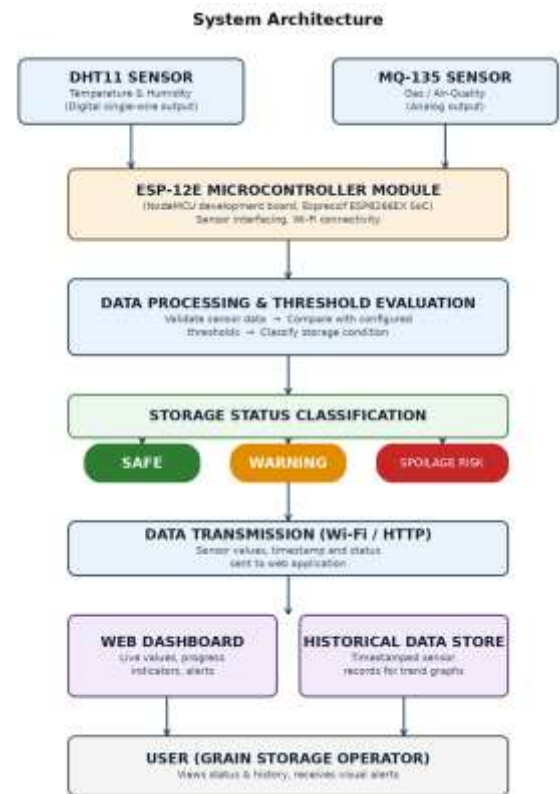


Fig. 1. System architecture of the proposed Smart Grain Storage and Spoilage Detection System.

A. DHT11 Sensor

The DHT11 sensor is used to measure temperature and relative humidity [18]. It provides digital sensor information that can be read by a suitable microcontroller.

The temperature measurement provides information about the thermal condition of the storage environment. The humidity measurement provides information about moisture-related environmental changes.

B. MQ-135 Sensor

The MQ-135 is used to monitor air-quality or gas-level variation [19]. Its output can change according to environmental gas conditions.

In the proposed system, the MQ-135 is used as a supplementary environmental indicator. Its output should be calibrated according to the intended application and should not be considered a direct laboratory measurement of grain-spoilage gases.

C. Processing Unit

The processing unit is an ESP-12E Wi-Fi microcontroller module (built around the Espressif ESP8266EX SoC), mounted on a NodeMCU development board, which collects the sensor measurements and performs basic data processing [20]. It can periodically transmit the readings to the web application.

The ESP-12E module performs the following functions:

- Sensor initialization.
- Temperature acquisition.
- Humidity acquisition.
- MQ-135 data acquisition.
- Sensor-value validation.
- Threshold evaluation.
- Status generation.



- Data transmission.

IV. PROPOSED METHODOLOGY

The proposed methodology is divided into five major stages: data acquisition, preprocessing, threshold evaluation, data storage, and dashboard visualization.

A. Data Acquisition

The system periodically reads temperature and humidity from the DHT11 sensor and obtains the gas/air-quality reading from the MQ-135 sensor.

Each monitoring cycle can generate a data record containing:

Parameter	Description
Temperature	Temperature measured using DHT11
Humidity	Relative humidity measured using DHT11
Gas Level	MQ-135 sensor reading
Timestamp	Time of measurement
Status	Evaluated storage condition

B. Data Processing

The collected readings are checked before being used for status evaluation. The system can identify missing or invalid sensor readings and prevent them from being incorrectly interpreted as normal storage conditions.

The valid sensor values are then compared with predefined threshold values.

A generalized status function can be represented as:

$$S=f(T,H,G)$$

where T is temperature, H is humidity, and G is the gas-level reading.

The status is determined according to configured operating conditions.

C. Threshold-Based Classification

The proposed system uses three levels of status classification.

SAFE

The system generates SAFE when the monitored parameters remain within their configured acceptable ranges.

WARNING

WARNING is generated when one or more parameters move outside the preferred range and require user attention.

SPOILAGE RISK

SPOILAGE RISK is generated when one or more parameters reach the configured critical condition.

The threshold values should be selected based on the grain type, storage environment, sensor characteristics, and experimental calibration [11], [12]. A universal threshold should not be assumed to represent actual spoilage for every type of grain.

D. Historical Data

Sensor measurements can be stored with timestamps to create a historical record, an approach consistent with recent sensor- and machine-learning-based grain-quality monitoring studies [11], [13], [14] record. Historical data allows users to observe trends rather than relying only on a single sensor reading.

For example, the system can identify whether:

- Temperature is gradually increasing.
- Humidity is increasing.
- Gas-level measurements are changing.
- Warning conditions are occurring repeatedly.

E. Dashboard Visualization

The web dashboard provides an interactive interface for viewing the collected information.

The dashboard contains:

- Live temperature value.
- Live humidity value.
- Live MQ-135 value.
- Progress indicators.
- Sensor history graphs.
- Current system status.
- Warning messages.
- Spoilage-risk alerts.

V. SYSTEM IMPLEMENTATION

The implementation consists of hardware and software components.

A. Hardware Implementation

The DHT11 and MQ-135 sensors are connected to the ESP-12E module mounted on the NodeMCU development board. The sensors are positioned so that they can monitor the environmental conditions of the grain-storage area, as shown in Fig. 2.

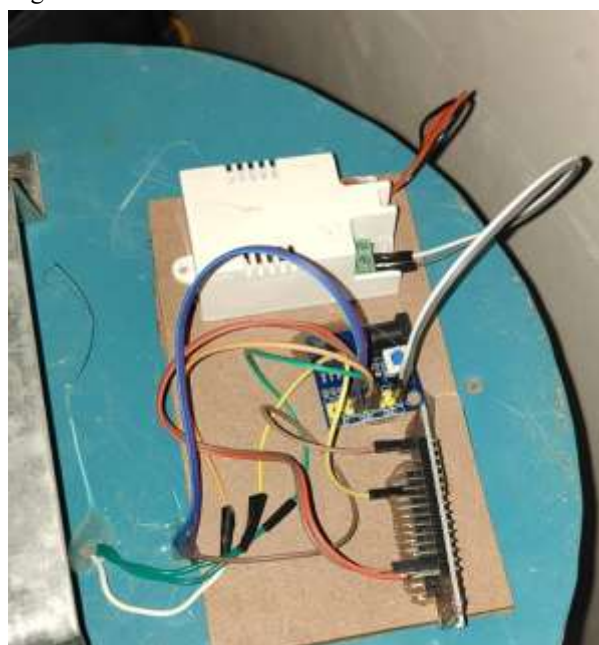


Fig. 2. Sensor wiring and interface circuit of the prototype.

The DHT11 provides temperature and humidity information. The MQ-135 provides a gas/air-quality signal. The ESP-12E module collects both readings and communicates the data to the monitoring application. The MQ-135 sensor is mounted through the storage-container lid, as shown in Fig. 3.



Fig. 3. MQ-135 gas sensor mounted on the storage container lid.

The physical enclosure is a cylindrical barrel mounted on a tripod stand, with the ESP-12E module and associated wiring

mounted on the lid. The CAD assembly drawing in Fig. 4 shows an overall height of approximately 915 mm, a container diameter of approximately 351 mm, and an outlet diameter of approximately 65 mm.



Fig. 4. CAD assembly drawing of the grain storage container (dimensions in mm).

A suitable regulated power supply should be provided to the ESP-12E module and sensors. Proper electrical connections are required to ensure stable operation.

B. Software Implementation

The software component receives sensor information and performs the monitoring process.

The main software sequence is:

1. Initialize the system.
2. Initialize DHT11.
3. Initialize MQ-135.
4. Read temperature.
5. Read humidity.
6. Read gas-level information.
7. Validate sensor data.
8. Compare values with configured thresholds.
9. Generate SAFE, WARNING, or SPOILAGE RISK status.
10. Update the dashboard.
11. Store historical sensor data.
12. Display alert messages.
13. Repeat the process.

C. Dashboard Design

The dashboard is designed to provide a simple interpretation of sensor information.

The current values can be presented using numerical cards and progress indicators. Historical data can be represented using line graphs. The overall system condition can be displayed using a prominent status indicator.

A typical dashboard structure is:

Temperature | Humidity | Gas Level

Current System Status

Sensor History Graph

Alert / Notification Area

This arrangement allows users to identify both current conditions and historical changes. The complete fabricated prototype integrating the storage container, sensor assembly, ESP-12E module, and supporting wiring is shown in Fig. 5.



Fig. 5. Fabricated Smart Grain Storage and Spoilage Detection System prototype.

VI. ALGORITHM

Input: Temperature T, Humidity H, Gas Level G

Output: Storage Status

1. Start.
2. Initialize sensors and ESP-12E module.
3. Read T from DHT11.
4. Read H from DHT11.
5. Read G from MQ-135.
6. Validate sensor readings.
7. Compare T, H, and G with configured thresholds.
8. If all parameters are within acceptable limits, set status to SAFE.
9. If one or more parameters require attention, set status to WARNING.
10. If a parameter reaches a configured critical condition, set status to SPOILAGE RISK.
11. Store the readings with timestamp.
12. Update the web dashboard.
13. Generate an alert when WARNING or SPOILAGE RISK is detected.
14. Repeat continuously.



VII. RESULTS AND DISCUSSION

The proposed system is designed to provide continuous visibility of the grain-storage environment. The primary output is a web dashboard showing current temperature, humidity, MQ-135 gas-level information, historical trends, and the current storage status, with representative SAFE, WARNING, and SPOILAGE RISK views shown in Fig. 6.

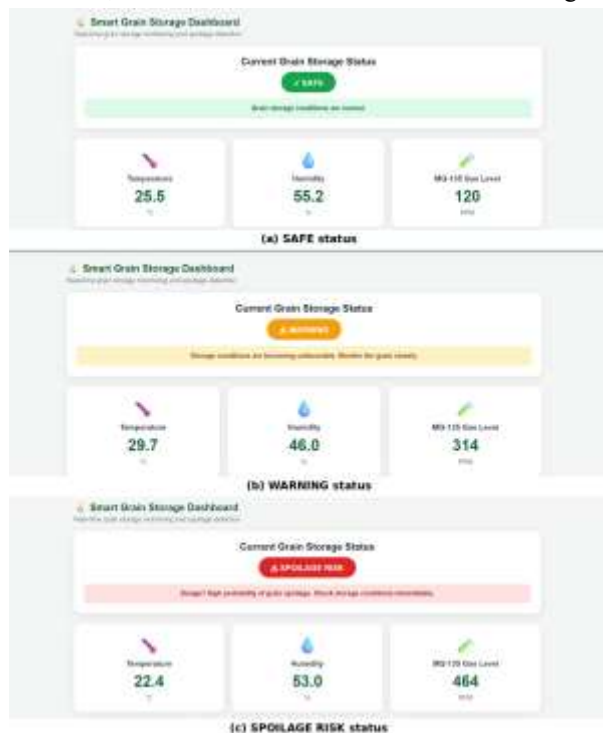


Fig. 6. Web dashboard views under different storage-status classifications.

The three-level classification simplifies interpretation of sensor measurements. Users do not need to continuously analyze individual numerical values because the system provides a summarized status.

Historical graphs provide additional information by showing changes over time. For example, a gradual increase in humidity can be identified from the trend even when an individual measurement does not appear critical.

The proposed system can therefore support early identification of potentially unfavourable environmental conditions [2], [4]. However, the SPOILAGE RISK status represents a **sensor-based environmental warning** and should not be interpreted as definitive proof that grain spoilage has occurred.

The effectiveness of the system depends on appropriate sensor placement, calibration, threshold selection, and validation for the intended grain-storage environment. DHT11 and MQ-135 are suitable for a low-cost prototype, while industrial applications may require higher-precision sensors and additional parameters [8], [15].

VIII. ADVANTAGES AND LIMITATIONS

A. Advantages

The proposed system provides the following advantages:

- Continuous environmental monitoring.
- Real-time sensor visualization.
- Automated threshold-based status evaluation.
- Easy-to-understand SAFE/WARNING/SPOILAGE RISK classification.

- Historical sensor monitoring.
- Visual alerts.
- Low-cost prototype implementation.
- Simple and user-friendly web interface.
- Expandable architecture.

B. Limitations

The proposed system also has certain limitations. The DHT11 provides basic environmental measurements and may not be suitable for applications requiring high measurement accuracy. The MQ-135 is a general-purpose gas/air-quality sensor and its response can be affected by multiple environmental factors.

The threshold-based status depends on correctly configured limits. Different grain types and storage environments may require different thresholds. Furthermore, the system monitors selected environmental parameters and does not directly measure all factors affecting grain quality.

Consequently, the proposed system should be considered an environmental monitoring and early-warning system rather than a complete laboratory-based grain-quality assessment system.

IX. FUTURE SCOPE

The system can be improved by integrating higher-precision temperature and humidity sensors and additional gas sensors. Grain moisture sensors can also be added to provide more direct information related to storage quality.

A cloud-based database can be incorporated for long-term storage and remote access to historical sensor information [2], [3]. Mobile applications, SMS, e-mail, or other notification mechanisms can be added for remote alerts.

Machine-learning methods can also be investigated in future work [9], [10]. Historical sensor measurements combined with experimentally verified grain-quality information could be used to develop predictive models for storage-risk assessment, following approaches demonstrated for other stored commodities [11]–[14].

Automatic control mechanisms can additionally be integrated [6], [7], [22]. For example, ventilation or cooling equipment could be activated when environmental conditions exceed configured limits.

X. CONCLUSION

This paper presented a **Smart Grain Storage and Spoilage Detection System** for continuous monitoring of environmental conditions in grain-storage environments. The proposed system uses DHT11 for temperature and humidity monitoring and MQ-135 for gas/air-quality variation monitoring.

The sensor readings are processed and evaluated using configurable threshold conditions. The resulting condition is classified into SAFE, WARNING, or SPOILAGE RISK and presented through an interactive web dashboard. The dashboard provides live sensor values, progress indicators, historical graphs, system status, and alert messages.

The proposed system provides a low-cost approach for improving visibility of storage-environment conditions and can help users identify potentially unfavourable changes at an early stage [4], [15], [17]. Its practical performance depends on sensor calibration, appropriate threshold selection, and validation for the particular grain and storage environment.



Future development can incorporate additional sensors, cloud connectivity, mobile notifications, machine-learning-based prediction, and automatic environmental control to create a more comprehensive smart grain-storage management system.

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