

Prototype of Smart Grain Storage based Internet of Things

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ARTICLE INFO

Article history:
Published

Keywords:
Smart Storage
Internet of Things
Humidity
Temperature
Rice Grains

ABSTRACT

Rice (*Oryza sativa* L.) is a crucial staple food, particularly in Indonesia, one of the largest rice-producing countries. Proper storage of rice grains is essential to maintain their quality and quantity. This research aims to develop a smart rice grain storage prototype based on the Internet of Things (IoT) that can monitor temperature, humidity, and light intensity in real-time. The method used is Design-Based Research (DBR), involving six stages: focus, understanding, definition, conception, creation, and testing. The prototype utilizes DHT22 sensors for temperature and humidity, LDR sensors for light intensity, and soil moisture sensors, all integrated with an ESP32 microcontroller. Data collected from the sensors are sent to a cloud-based platform for analysis and early warnings if storage conditions are unsuitable. The results indicate that the prototype effectively monitors storage conditions and provides accurate data. System testing shows that all components function according to specifications. This prototype helps maintain grain quality and reduce damage risk during storage. The use of IoT in grain storage enhances efficiency and reduces farmers' costs. Future research should focus on developing more advanced prototypes with automatic control features and mobile application integration.

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I. Introduction

Rice (*Oryza sativa* L.) is a staple food for millions of people around the globe, offering essential energy, vitamins, and minerals [1]. Over half of the global population depends mainly on rice for their dietary needs [2]. Especially in Indonesia, which is one of the largest rice-producing countries. Grain is the harvested product of rice that is still in the form of skinned grains. After harvesting, the grain must go through a drying and storage process before being further processed into rice. Good grain storage is very important to maintain the quality and quantity of grain so that it remains suitable for consumption and has high economic value. Proper storage of rice is critical during its journey from harvest to consumption, which greatly impacts food security. Although losses occur at various points in the supply chain, storage-related losses are considered the most significant [3]. Advances in information technology are a demand for every government and private institution to facilitate the delivery of information and support work systems [4].

Grain storage often faces various challenges, especially changes in environmental conditions such as humidity and temperature. High humidity can cause mould and bacteria growth, while unstable temperatures can affect grain quality. Therefore, maintaining optimal grain storage conditions is essential to prevent damage and yield loss [5]. The Internet of Things (IoT)-based smart grain storage prototype we developed offers a solution to this problem. The system is equipped with sensors to measure humidity, temperature, and light inside the storage bin. Light is one of the factors that indirectly affect temperature and humidity [6]. The data collected by these sensors is sent to a cloud-based platform for real-time analysis. Based on the analysis, the system can provide recommendations to keep the grain in optimal condition.

The advent of the internet revolutionized communication by allowing people to exchange information across vast distances. As technology advances, the internet's capabilities extend beyond



smartphones and computers, allowing various objects to connect and interact, leading to the development of the Internet of Things (IoT) [7]. By using IoT technology, this prototype enables automatic and efficient monitoring and management of grain storage conditions. The implementation of this system is expected to increase storage efficiency and reduce grain losses due to inappropriate environmental conditions. The Internet of Things technology allows for the integration and easy access to data collected from various sensors through a website, facilitating effective monitoring and timely decision-making [8]. This device not only has the potential to reduce costs and losses for farmers but can also help improve the quality of crops, ultimately supporting national food security.

II. Method

The development of this prototype was carried out using a Design-Based Research (DBR) approach. DBR is based on the relationship between design, scientific methods, and real-world problems. The DBR process involves six steps : (1) focus, (2) understand, (3) define, (4) conceive, (5) build, and (6) test [9].

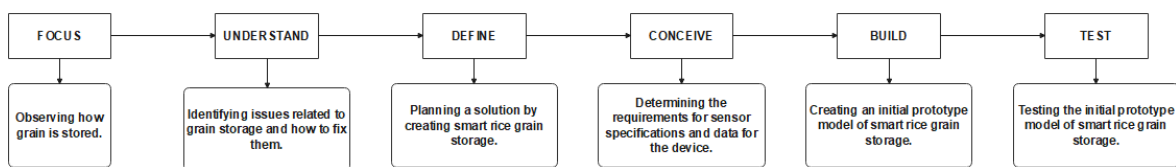


Fig. 1. DBR Method

The results of this research are expected to be a breakthrough in the innovation of grain storage systems, making it possible to enhance storage efficiency and reduce grain losses due to inappropriate environmental conditions. This innovation not only has the potential to reduce costs and losses for farmers but also to improve crop quality, ultimately supporting national food security.

III. Results and Discussion

A. Focus and understand

The focus and understanding stage is the stage used to determine the topic, scope, and research problems. The topic discussed in this research is the development of an IoT-based smart grain storage prototype in Gondang Hamlet, Pasekan Village, Eromoko District, Wonogiri Regency. Observations were conducted in Gondang Hamlet, where the traditional grain storage system often experiences problems such as uncontrolled changes in temperature and humidity. From the results of interviews with farmers in the hamlet, information was obtained that the main problem was the need for an efficient and accurate monitoring system to maintain optimal grain storage conditions. Therefore, it is necessary to build a smart grain storage system that can monitor and provide warnings when the humidity level exceeds the specified threshold of 15% . The system supports energy efficiency and minimizes losses by alerting users to take necessary actions to maintain optimal storage conditions.



Fig. 2. Traditional storage of rice grains

B. Define

Furthermore, the define phase is used to analyze the problems that arise and identify the initial concept of the solution offered. The concept offered includes several main parts. First, a device capable of measuring temperature, humidity, and light must be installed to monitor grain storage conditions in real time. The data collected by the device is then sent to the cloud platform for analysis. The last step is the provision of recommendations based on data analysis to maintain optimal grain storage conditions. Details of the three parts are shown in Figure 3.

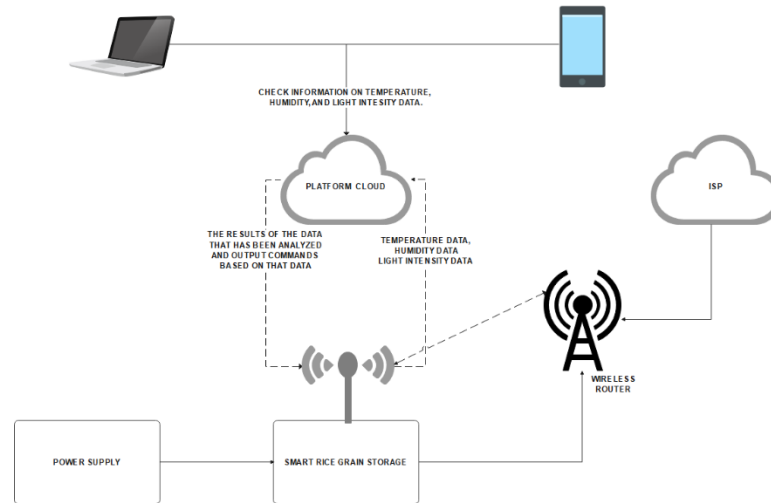


Fig. 3. Design of IoT-based smart rice grain storage prototype

C. Conceive

Upon reviewing the design results, the next step is to analyze the device requirements for developing the IoT-based smart rice grain storage prototype, as shown in Table 1.

Table 1. Device requirements analysis

Part name	Required Devices
Smart rice grain storage	- Temperature sensor
	- Humidity sensor
	- Light sensor
	- Esp32 microcontroller
	- Buzzer
	- LCD
Platform cloud	- Domain
	- Cloud storage server

D. Build

The build phase involves several key steps in developing and implementing the prototype of the smart rice grain storage system based on the Internet of Things (IoT). This process includes selecting components, assembling hardware, developing software, and integrating the entire system. Below are the detailed steps in the build process:

a. Component Selection

In the initial stage, the main components required for this prototype are selected. These components include:

- Temperature Sensors: *DHT22 Sensor*
- Humidity: *Soil Moisture Sensor*
- Microcontroller: *esp32*

- Light Intensity Sensor: *LDR Sensor (Light Dependant Resistor)*
- Buzzer
- LCD

b. Hardware Assembly

Once all components are selected, the next step is hardware assembly. Sensors and the IoT module are installed in the grain storage unit and connected to the microcontroller. This setup ensures that the sensors can accurately measure and transmit environmental condition data.



Fig. 4. Assembly process

c. Software Development

Software is developed to control the microcontroller and manage data from the sensors. This software is responsible for:

- Collecting data from the sensors periodically.
- Sending data to the cloud platform for further analysis.
- Providing a user interface to monitor storage conditions in real time.

The user interface is designed to be user-friendly and provides real-time updates on the storage conditions. Below, screenshots of the completed website interface are included to illustrate its functionality and layout.

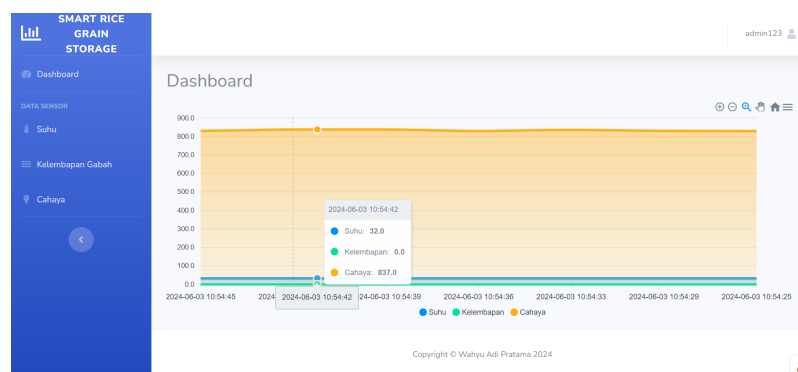


Fig. 5. Dashboard menu

This page displays the temperature, grain moisture, and light intensity sensor data in the form of a line graph. Each parameter is marked with a different color (blue for temperature, green for moisture, and orange for light). The data is displayed in real-time and can be hovered over to view specific values at any given time.

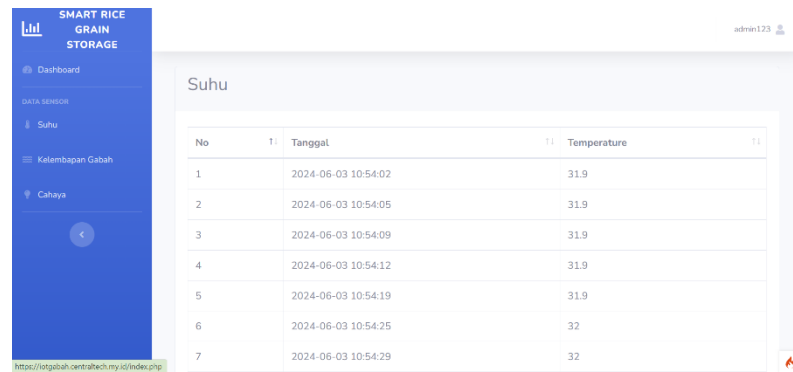


Fig. 6. Temperature menu

This page displays the temperature data recorded by the sensor in table form. The table includes columns for the sequence number, recording date and time, and temperature value in degrees Celsius. The data is sorted by recording time, making it easier for users to monitor temperature changes.

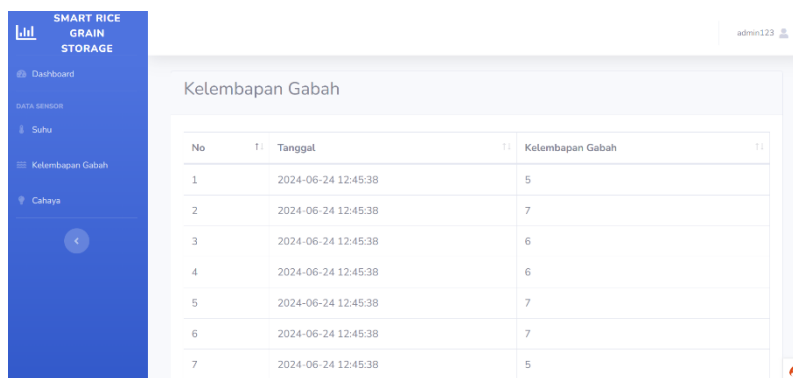


Fig. 7. Grain moisture menu

The "Grain Moisture" menu on the Smart Rice Grain Storage dashboard displays data related to grain moisture measured in percent (%). Each data entry consists of a sequence number (No), measurement date and time (Date), and grain moisture value (Grain Moisture). The graph used to display this data is a table graph that makes it easy for users to monitor changes in grain moisture chronologically. This data is important to ensure that grain storage conditions remain optimal, avoiding the risk of damage or deterioration of grain quality due to inappropriate moisture.

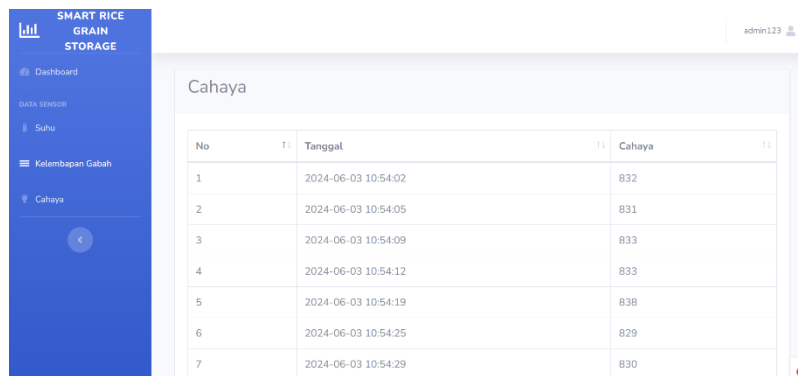


Fig. 8. Light intensity menu

The "Light Intensity" menu on the Smart Rice Grain Storage dashboard displays information related to the light intensity level inside the rice storage measured in standard units, such as lux (lx) or other light units. Each data entry includes a sequence number (No), measurement date and time (Date), as well as the detected light intensity value (Light

Intensity). The table graph used allows users to easily view changes in light intensity over time, providing chronological monitoring of the environmental conditions of rice storage.

d. System Integration

After the hardware and software are ready, the next step is to integrate all components into a cohesive system. Initial testing is conducted to ensure that all parts work as expected.

e. Device usage

Once the system is tested and ready for use, the next step is demonstrating how to use the device. Here are the steps for using the device, which can be visualized in a flowchart:

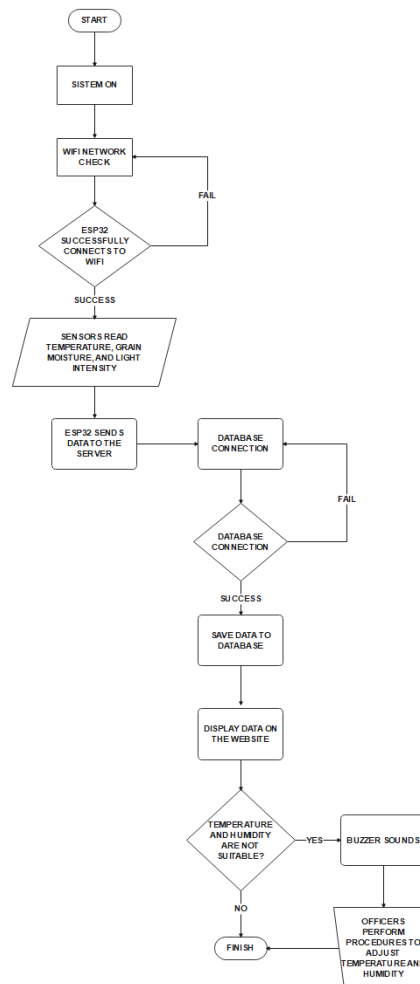


Fig. 9. Device usage flowchart

This build process results in a prototype of a smart rice grain storage system that can automatically and efficiently monitor and control environmental conditions. The device is expected to improve storage efficiency and reduce grain loss due to suboptimal storage conditions.

E. Test

Testing is carried out to ensure that the smart rice grain storage prototype can function in accordance with the expected specifications. This test includes several critical steps to validate the overall performance and reliability of the system. The initial step involves system initialization, which prepares all components and subsystems for operation. This is followed by the retrieval of data from various sensors that monitor key parameters such as temperature, humidity, and light intensity. The data collected from these sensors is then displayed on the LCD screen, allowing for real-time monitoring and verification of the environmental conditions within the storage unit. Furthermore, the system transmits this data to a remote server, facilitating continuous data logging and remote access. An additional feature includes the activation of a buzzer based on specific conditions received from

the server, serving as an alert mechanism to notify users of any deviations from the desired storage conditions. These comprehensive tests ensure that the prototype operates efficiently and effectively, minimizing postharvest losses and maintaining the quality of stored rice grains.

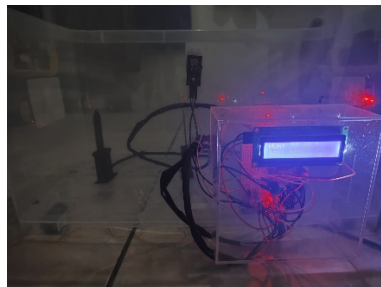



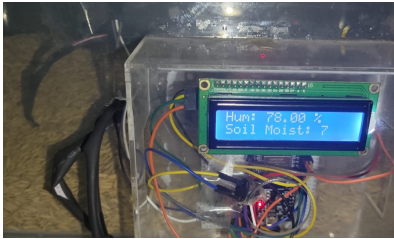
Fig. 10. Device testing



Fig. 11. LCD Display

Table 2. Device testing table

NO	Type of testing	Result	Documentation	Status																								
1	System Initialization	System successfully initialized		Passed																								
2	Sensor Data Capture	Sensor data is accurate and within specification	<table border="1"> <thead> <tr> <th>id</th> <th>suhu</th> <th>kelembapan_gabah</th> <th>cahaya</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>31.9</td> <td>5</td> <td>832</td> </tr> <tr> <td>2</td> <td>31.5</td> <td>7</td> <td>831</td> </tr> <tr> <td>3</td> <td>31.7</td> <td>6</td> <td>833</td> </tr> <tr> <td>4</td> <td>31.9</td> <td>6</td> <td>833</td> </tr> <tr> <td>5</td> <td>31.4</td> <td>7</td> <td>838</td> </tr> </tbody> </table>	id	suhu	kelembapan_gabah	cahaya	1	31.9	5	832	2	31.5	7	831	3	31.7	6	833	4	31.9	6	833	5	31.4	7	838	Passed
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3	Data Display on LCD	Data displayed clearly on the LCD		Passed
4	Data Transmission to Server	Data successfully transmitted to the server	<pre> HTTP Response Code: 200 Server Respon: { "status": 40, "kondisi": "AMAN" } kondisi terkini: AMAN </pre>	Passed
5	Buzzer Activation	Buzzer activated based on server conditions		Passed

The table above shows the test results of the Internet of Things (IoT) based smart grain storage device. This test includes several important aspects to ensure that all the main functions of the device are working properly. Firstly, the initialization of the system was performed successfully, which shows that the system can start properly without any errors. Secondly, the sensor data capture showed accurate results and conformed to the specified specifications, ensuring that the data collected was reliable. Next, the data display on the LCD shows that the data is clearly displayed, making it easy for users to monitor the condition of the device. Data transmission to the server was also successfully performed, showing that the device can transmit data effectively for remote monitoring. Finally, the activation of the buzzer based on the server conditions was successfully performed, showing that the system can provide timely alerts based on the detected conditions. All of these tests passed with a “Passed” status, indicating that the device works well as expected.

Table 3. Results of data transmission and capture by the device

Temperature	Humidity	Light Intensity
31,9	7%	830
32	7%	837
32	6%	837
31,9	7%	829
31,9	4%	835

The smart rice grain storage prototype is constructed using several components. The use of the ESP32 as the primary component is supported by research demonstrating its reliability in IoT systems. For instance, a study by [10] showed that the ESP32 can be used to develop an IoT-based package inbox monitoring system capable of sending notifications and photos via the Telegram app. Another study by [11] utilized the ESP32 to create a web-based door monitoring tool that sends notifications through Telegram. These studies illustrate that the ESP32 is highly capable of developing effective and efficient IoT systems.

The next component is the DHT22 sensor, which measures temperature and humidity in the rice storage area. Research by [12] found that the DHT22 sensor provides accurate readings for temperature and humidity, making it a popular choice for various environmental monitoring applications. Additionally, an LDR sensor is used to measure light intensity in the storage area. A study conducted by [6] concluded that light is a factor affecting temperature and humidity conditions in storage areas. Another study by [13] used the LDR sensor to measure light intensity in a room, with data processed by the NodeMCU ESP8266 to control lights manually or automatically based on the determined lighting levels, proving the reliability of the LDR sensor.

Furthermore, a soil moisture sensor is employed to directly monitor the moisture levels in the rice stored in sacks. Research by [14] discovered that this sensor is versatile and can be used for other objects such as grains, including rice. Three soil moisture sensors are used to cover all parts of the rice in the sack, ensuring comprehensive and accurate data collection. The data from these sensors are sent to the ESP32, which then displays the information on an LCD and transmits it to a website for processing and display. The website can also send commands back to the ESP32; for instance, if the moisture data indicate that the moisture content exceeds the acceptable level of less than 15% [15], the ESP32 will activate a buzzer as a warning. This combination of components ensures that the smart rice grain storage prototype is both effective and well-implemented.

IV. Conclusion

Based on the results of the research conducted, it can be concluded that the IoT-based smart rice grain storage prototype capable of real-time monitoring has been successfully made. This prototype is able to effectively monitor storage conditions by using DHT22 sensors for temperature and humidity, LDR sensors for light intensity, and soil moisture sensors. All of these sensors are integrated with the ESP32 microcontroller. The developed prototype is able to provide accurate data and provide early warning if the storage conditions are not as expected. Thus, this prototype can help maintain grain quality and reduce the risk of damage during storage. For future research, it is recommended that a more sophisticated prototype with additional features, such as automatic control, be developed based on monitored conditions. In addition, integration with mobile applications is also recommended to increase accessibility and ease of users in monitoring and controlling grain storage conditions from anywhere and anytime.

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