Smart Grain Drying System Using Raspberry Pi Pico with Automated Humidity Control and Temperature Regulation

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Abstract

The increasing demand for efficient post-harvest management in agriculture has highlighted the need for advanced grain drying solutions, as nearly 30–40% of global agricultural produce is lost annually due to improper storage and drying techniques, while traditional drying methods can consume up to 25% more energy compared to optimized systems. These environments require adaptable systems capable of maintaining optimal drying conditions under varying climatic factors. Conventional grain drying methods are labor-intensive, time-consuming, and lack precise temperature control, often resulting in over-drying or under-drying, which degrades grain quality and increases post-harvest losses. Additionally, manual monitoring leads to inefficiencies, inconsistent results, and higher energy consumption. To address these challenges, the proposed Raspberry Pi Pico-controlled temperature-controlled harvester introduces an automated and intelligent grain drying system. The system integrates temperature sensors, a fan-based airflow mechanism, and a Raspberry Pi Pico microcontroller to continuously monitor and regulate the drying environment. Real-time data acquisition enables adaptive control of temperature levels, ensuring uniform and optimal drying conditions. The user interface allows farmers to set desired parameters, while the system autonomously adjusts operations based on environmental variations. This energy-efficient design minimizes resource utilization while improving drying accuracy and consistency. Finally, the proposed solution enhances grain quality, reduces post-harvest losses, and supports sustainable and smart agricultural practices through automation and precision control.

Keywords: Agricultural Automation, Energy Efficiency, Grain Drying System, Post-Harvest Management, Precision Agriculture, Raspberry Pi Pico, Smart Farming, Temperature Control

1. Introduction

The agricultural sector [1] is undergoing rapid modernization to meet the increasing global food demand, with post-harvest management playing a crucial role in ensuring food quality and reducing losses. It is estimated that nearly 20–30% of harvested grains are lost annually due to improper drying, storage, and handling practices [2]. Additionally, agriculture contributes significantly to the global economy, supporting the livelihoods of over 2.5 billion people worldwide. Efficient grain drying is essential to maintain moisture levels, prevent microbial growth, and enhance storage life [3]. With the adoption of smart farming technologies and automation, there is a growing demand for intelligent systems that can optimize post-harvest processes [4], improve productivity, and reduce dependency on manual labor.

Problem Statement: Traditional grain drying methods are largely manual and rely on natural sunlight or basic heating techniques, which lack precision and consistency [5]. Farmers often depend on environmental conditions such as temperature, humidity, and sunlight availability, making the drying process unpredictable and time-consuming [6]. These conventional approaches do not provide controlled environments, resulting in uneven drying and inconsistent grain quality. Moreover, manual monitoring increases labor effort and does not allow real-time adjustments, limiting efficiency [7]. The absence of automation and intelligent control systems further restricts scalability and adaptability in modern agricultural practices.

Research Motivation: In real-time scenarios, these limitations lead to several critical challenges affecting both productivity and grain quality [8]. Improper drying can result in over-drying, causing weight loss and reduced market value, or under-drying, leading to fungal growth and spoilage during storage. Variations in environmental conditions make it difficult to maintain optimal drying parameters, increasing the risk of post-harvest losses [9]. Additionally, labor-intensive processes increase operational costs and reduce efficiency, especially for large-scale farming. The lack of real-time monitoring and adaptive control prevents timely decision-making, making the process less reliable. These challenges highlight the need for an intelligent, automated solution capable of maintaining precise temperature control, adapting to environmental changes, and ensuring consistent, high-quality grain drying.

2. Literature Survey

Futagawa et al. [10] proposed a miniature integrated multimodal sensor capable of measuring pH, electrical conductivity (EC), and temperature for precision agriculture applications. Ramson et al. [11] proposed an overview of IoT applications that analyzed system architectures, communication protocols, and real-time data processing in various domains. The study highlighted the role of IoT in enabling smart monitoring and automation systems.

Pathinarupothi et al. [12] proposed an IoT-based smart edge framework for remote monitoring that incorporated severity detection and alert transmission using distributed edge devices. Fortino et al. [13] proposed a modeling approach for opportunistic IoT services in open ecosystems, focusing on dynamic service composition and interaction among heterogeneous devices.

Kuang et al. [14] proposed comprehensive sensing techniques for soil property analysis in laboratory, in situ, and on-line conditions. The study evaluated various sensing methods for accurate soil characterization and monitoring. Ramson et al. [15] proposed a wireless sensor network-based smart bin system that utilized distributed sensors for waste monitoring and management. The system enabled automated data collection and efficient waste handling through real-time communication.

Madhura et al. [16] proposed a soil quality management system using wireless sensor networks that monitored parameters such as moisture and nutrient levels for agricultural optimization. Villalba et al. [17] proposed a networked sensor system for analyzing plot-scale hydrology that integrated multiple sensing nodes to monitor water flow and soil conditions.

Estrada-López et al. [18] proposed a smart soil parameter estimation system using an autonomous wireless sensor network with dynamic power management strategies. Roy et al. [19] proposed an adaptive technique for soil moisture control and nutrient monitoring using wireless sensor networks that adjusted irrigation based on real-time soil conditions. Vieira et al. [20] proposed the design of a long-range wireless sensor network for precision irrigation that enabled wide-area monitoring and control of agricultural fields.

3. Proposed System

In this innovative work, a functional model of a temperature-controlled harvester has been meticulously crafted as presented in Figure 1, incorporating a variety of essential components to optimize the grain drying process. The system is equipped with a suite of key elements, including a temperature sensor, humidity sensor, mode switches for both heating and engine temperature control, and Raspberry Pi Pico microcontroller, an LCD display, a DC fan, and an AC heater.

The functionality of the harvester is enhanced by the strategic placement of a humidity sensor within the grains chamber. This sensor diligently monitors the humidity levels in the grains and transmits real-time data to the Raspberry Pi Pico microcontroller. Upon sensing the need for drying, the controller promptly activates the AC heater, initiating the drying process. As the grains reach the desired dryness level, the humidity decreases, prompting the controller to deactivate the heater, ensuring optimal grain quality.

Recognizing the potential overheating of the harvester's engine during the drying process, a temperature sensor is thoughtfully positioned near the engine. In the event of engine overheating, the system triggers the activation of a DC fan. This proactive measure serves to safeguard the harvester's engine, preventing potential damage due to excessive heat.

The introduction of mode switches adds a layer of versatility to the system. These switches allow for a seamless transition between auto-mode and manual mode for the heater. This feature provides users with the flexibility to manually control the heating process when necessary, offering a practical solution for specific operational scenarios.

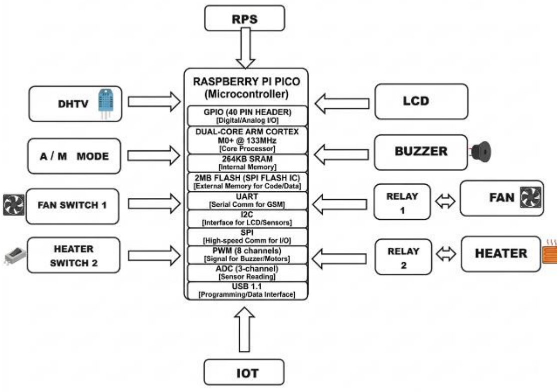


Figure 1. Proposed System Architecture.

Finally, this temperature-controlled harvester model demonstrates a comprehensive and intelligent approach to grain drying. By integrating sensors, switches, and a Raspberry Pi Pico microcontroller, the system ensures precise control over the drying environment, promoting efficiency, and safeguarding the harvester's engine. The inclusion of manual control options enhances user adaptability, making this model a practical and effective solution for optimizing the grain drying process in agricultural setting.

3.1 Working Procedure

The proposed system totally contains four sections/modules such as Regulated power supply (RPS), Input Section, Output Section Raspberry pi pico Mirco Controller.

Figure 2 shows the flowchart of proposed work. The RPS module converts the 230 volts into 5V of dc. The 5v of power supply goes to all components in the system. The Input of the project is Temperature and Humidity sensor, mode switch, manual switches. The Temperature and Humidity sensor (DH11) is used to sense the wet percentage of Grains/Beans in the drum. The mode switch is used for switching the modes either manually or automatically, and two manual switches are provided in the circuit i.e, fan and heater switches by manual mode of operation.

The output module has LCD, Buzzer, IOT, Relay-1 is attached with DC fan and Relay2 is attached with heater. The IOT server can send the data and display the data in web server app. In Raspberry pi pico microcontroller contains the software programming code in embedded C. The main purpose of the microcontroller is to process the data and then controlling the data. Once we should on the kit, we need to reset the kit because to connect wifi to IOT server. The kit is reset and then the LED displays "Temperature Control Harvester". After we configure to IOT server by using a web application.

Once the mobile data of your mobile is ON and connect your hotspot to the circuit, so that it can access internet for uploading the data of temperature and humidity levels of the grains in web application. The DH11 sensor sense the temperature and humidity levels in the grains and displays it on LCD. In Automatic mode the microcontroller receives the data from the sensor and performs the operation of grain drying. We can also operate this circuit by using the manual mode function. Finally, the grains are ready for packing and selling.

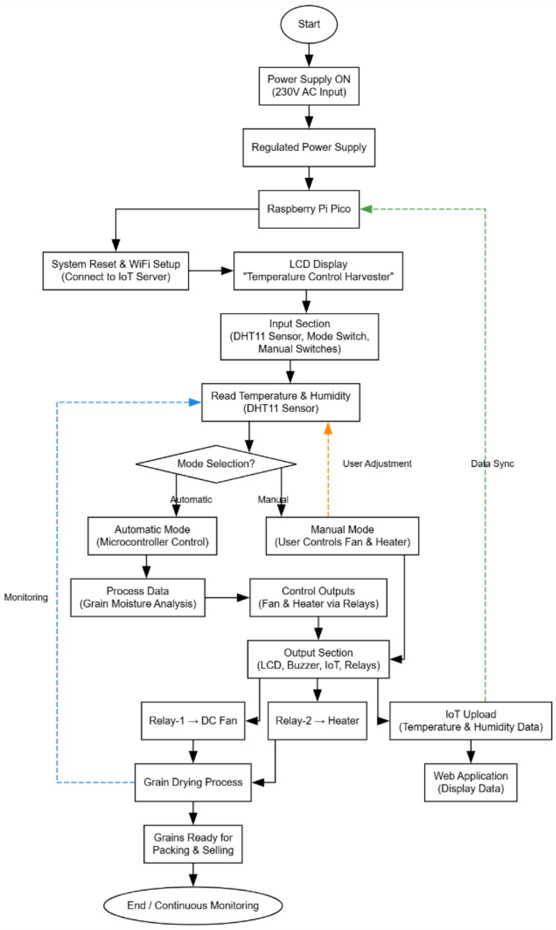


Figure 2. Proposed System Working Procedure.

4. Results and Discussion

Figure 3 illustrates the initial stage of the system where a RPS provides 12V input, which is then stepped down and converted into a stable 5V DC supply required for the operation of the circuit. The LED connected in this stage acts as a visual indicator to confirm the presence of the 5V output. When the conversion is successful, the LED glows, indicating that the power supply is functioning correctly and that all connected hardware components are receiving the required voltage for proper operation. This stage ensures safe and reliable power distribution across the entire system.

Figure 4 represents the system startup process after the reset button is pressed. Once the regulated power supply is provided and the system initializes, the display unit shows the message "Temperature Control Harvester," confirming that the microcontroller has successfully booted and the program has started executing. Additionally, the IoT module is connected through a Wi-Fi network, enabling remote communication and monitoring. This stage verifies both hardware initialization and successful network connectivity required for real-time data transmission.

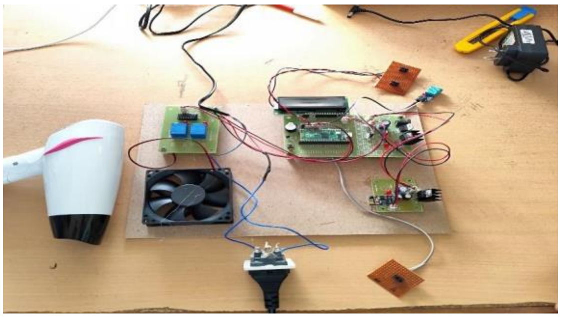


Figure 3. Hardware Setup.

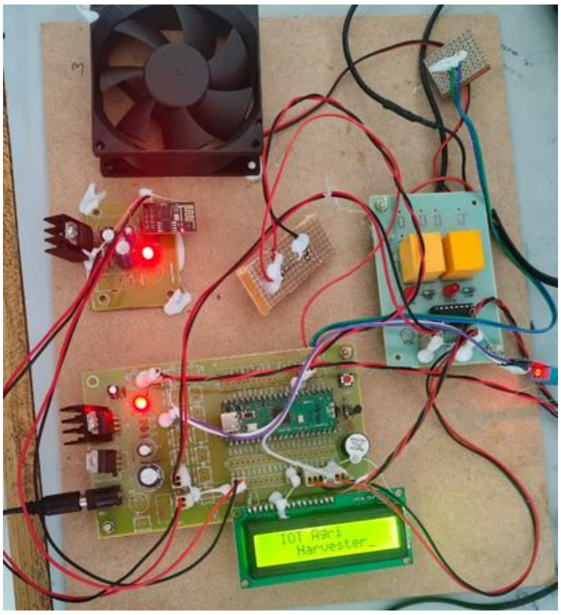
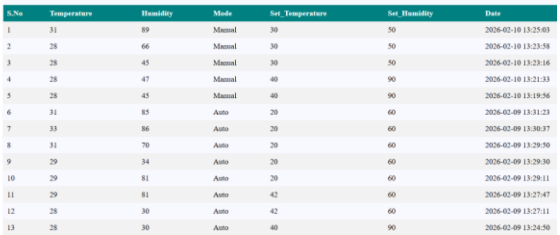


Figure 4. System Initialization and Display Output

Figure 5 shows the real-time monitoring of temperature and humidity values using the sensor module integrated into the system. The LED display presents the sensed environmental parameters, allowing users to observe grain conditions continuously. Based on the humidity levels, the system automatically determines the operational mode using predefined thresholds. The displayed values provide clear insight into the drying requirements, ensuring that the grain processing conditions are maintained efficiently.

Figure 5. Temperature and Humidity Monitoring Output.

Figure 6 depicts the output response of the microcontroller when high humidity levels are detected in grains. In such conditions, the system activates the heater to normalize moisture levels and improve grain quality. Simultaneously, the sensed data is transmitted and stored on a web platform through the IoT module, enabling remote monitoring and data analysis. This integration of control action and cloud storage enhances automation, traceability, and efficiency in grain drying operations.



S.No	Temperature	Humidity	Mode	Set_Temperature	Set_Humidity	Date
1	31	89	Manual	30	50	2026-02-10 13:25:03
2	28	66	Manual	30	50	2026-02-10 13:23:58
3	28	45	Manual	30	50	2026-02-10 13:23:16
4	28	47	Manual	40	90	2026-02-10 13:21:33
5	28	45	Manual	40	90	2026-02-10 13:19:56
6	31	85	Auto	20	60	2026-02-09 13:31:23
7	33	86	Auto	20	60	2026-02-09 13:30:37
8	31	70	Auto	20	60	2026-02-09 13:29:50
9	29	34	Auto	20	60	2026-02-09 13:29:30
10	29	81	Auto	20	60	2026-02-09 13:29:11
11	29	81	Auto	42	60	2026-02-09 13:27:47
12	28	30	Auto	42	60	2026-02-09 13:27:11
13	28	30	Auto	40	90	2026-02-09 13:24:50

Figure 6. IoT Data Logging Outcome.

5. Conclusion

The proposed Raspberry Pi Pico-controlled Temperature-Controlled Harvester offers an efficient and intelligent solution to address the challenges of traditional grain drying methods by incorporating automation, real-time monitoring, and precise temperature regulation. By utilizing temperature sensors and a fan-based airflow mechanism controlled through the Raspberry Pi Pico microcontroller, the system ensures uniform and optimal drying conditions, reducing the risks of over-drying or under-drying. Its ability to adapt to changing environmental conditions and operate autonomously minimizes human intervention, improves consistency, and significantly enhances energy efficiency. Furthermore, the user-friendly interface allows farmers to easily configure and monitor the drying process, making it practical for real-world agricultural applications. Finally, this system not only improves grain quality and reduces post-harvest losses but also promotes sustainable and smart farming practices, contributing to increased productivity and resource optimization in modern agriculture.

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