DESIGN AND FABRICATION OF PADDY DRYING SYSTEM WITH CONTROLLED AIR CIRCULATION

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ABSTRACT

An efficient and automated solution has been developed to improve the paddy drying process in agricultural applications. Traditional drying methods mainly rely on sunlight and weather conditions, which increase drying time and often cause uneven moisture removal. To address these problems, the proposed system uses controlled heating, grain rotation, and temperature monitoring for faster and uniform drying. A 12V DC gear motor (60 RPM) rotates a cylindrical drum to continuously mix the paddy, while a 230V hot air dryer supplies heated air for effective moisture removal. The frame is fabricated using arc welding to ensure strength and durability. An Arduino Uno connected to an L293D motor driver controls motor operation, and a temperature sensor automatically turns the heater OFF when the preset temperature is exceeded. An automatic discharge mechanism is also included for easy unloading of dried paddy. The developed system is economical, energy-efficient, and suitable for small and medium-scale farmers. It improves drying consistency, reduces post-harvest losses, enhances grain quality, and increases productivity with minimum manual labor.

Keywords: Arduino Uno, DC Gear Motor, L293D Motor Driver, Hot Air Dryer, Temperature Control, Paddy Drying, Agricultural Automation, Moisture Reduction, Smart Farming.

1. Introduction

Paddy is one of the major food grains produced across the world and is the primary source of nutrition for millions of people. After harvesting, drying is an essential process to lower the moisture content of paddy so that it can be stored safely for longer periods without spoilage. If drying is not carried out properly, grains may be affected by fungal growth, insect attack, discoloration, and breakage, which reduce both quality and market value. In many agricultural regions, open sun drying is commonly practiced, but this method is slow, weather-dependent, and often causes non-uniform drying due to irregular heat exposure and environmental contamination [1], [7]. To overcome these limitations, several researchers have developed mechanical drying systems that provide faster and more reliable moisture removal. Controlled drying methods such as deep-bed dryers, rotary dryers, microwave dryers, and fluidized bed dryers have shown better performance compared to traditional practices [3], [4], [6], [14]. These systems help in maintaining suitable drying temperatures and proper air circulation, which are important factors for preserving grain quality and reducing energy loss during operation [2], [5], [11]. Studies have also shown that improved drying methods contribute to better rice appearance, reduced cracking, and higher milling recovery [15].With the advancement of technology, automated drying systems are becoming more popular in agriculture. The use of sensors, microcontrollers, and smart monitoring devices makes it possible to regulate temperature, airflow, and drying duration automatically [12]. Mathematical models and simulation techniques have also been introduced to study drying behavior and optimize machine performance under different working conditions [9], [10]. Recent investigations further focus on energy-efficient dryers and quality preservation during drying and storage processes [18], [19], [20].

2. Literature review

Many researchers have worked on improving paddy drying systems to replace traditional sun drying. Jittanit [1] and Nimmol *et al.* [2] reported that proper heat control and airflow management can reduce energy consumption and improve drying efficiency. Tohidi *et al.* [3] found that deep-bed dryers require uniform air distribution for effective moisture removal. Firouzi *et al.* [4] showed that rotary dryers provide better mixing and uniform drying of grains. Kamruzzaman *et al.* [5] stated that drying temperature and air velocity greatly affect drying rate and grain quality. Jafari *et al.* [6] observed that microwave drying reduces drying time significantly. Nanvakenari *et al.* [14] and Du *et al.* [17] concluded that fluidized bed and infrared drying methods offer faster and more uniform drying. Nguyen-Van-Hung *et al.* [7] noted that many farmers still depend on open sun drying, while Mondal *et al.* [8] recommended low-cost mechanical dryers for small-scale farms. Hung *et al.* [9] and Le *et al.* [10] developed drying models to predict moisture removal and improve dryer design. Shu *et al.* [13], Zhang *et al.* [15], and Wang *et al.* [20] emphasized that controlled drying improves rice quality, reduces breakage, and increases storage life. Sanjeevi *et al.* [12] highlighted the use of IoT and sensors in agriculture. Li *et al.* [18] and Ying *et al.* [19] focused on optimization and modern smart drying technologies. These studies support the development of an automated paddy drying system with controlled air circulation.

3. Methodology

The developed work follows a practical engineering approach that includes planning, fabrication, component assembly, programming, and performance testing of an automated paddy drying unit. Earlier studies on paddy drying systems have shown that controlled heating, proper air circulation, and automation are important factors for improving drying efficiency, achieving uniform moisture removal, and maintaining grain quality [1], [3], [15]. Based on these observations, the proposed system is designed as a compact, economical, and efficient solution suitable for small and medium-scale farmers.

The first stage of methodology involves preparation of the dryer layout and selection of suitable components. A cylindrical drying chamber is selected to ensure continuous mixing of paddy during operation, similar to rotary drying principles reported in earlier studies [4]. Mild steel material is used for the frame and drum due to its strength, durability, and low cost. The structural frame is fabricated using arc welding to provide stability during operation. The second stage includes fabrication and mechanical assembly of the system. A 12V DC gear motor (60 RPM) is mounted to rotate the cylindrical drum through a shaft coupling arrangement. Continuous rotation ensures uniform exposure of grains to hot air, which helps in even moisture removal [5]. An up-down discharge mechanism is also provided for easy unloading of dried paddy.

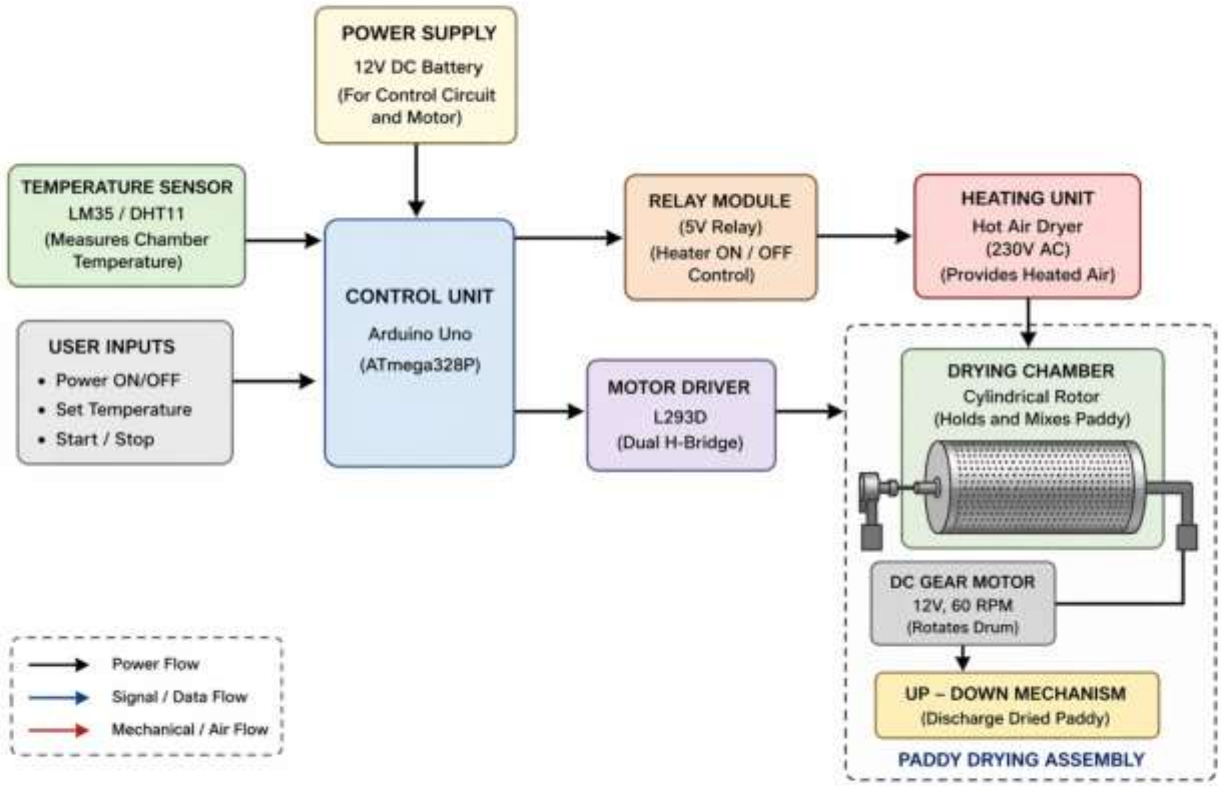

Fig .1. Block Diagram of Automated Paddy Drying System with Controlled Air Circulation

The third stage consists of heating and air circulation arrangement. A 230V hot air dryer is fixed at the inlet section to supply heated air into the chamber. Proper duct arrangement is provided to maintain uniform air circulation throughout the drying chamber. Research has shown that proper airflow distribution reduces drying time and improves drying consistency [2], [14]. The fourth stage focuses on automation and control. An Arduino Uno microcontroller is used as the main controller, while an L293D motor driver controls motor operation. A temperature sensor such as LM35/DHT11 continuously monitors the chamber temperature. When the temperature exceeds the preset limit, the Arduino automatically switches OFF the heater through a relay module to prevent overheating and maintain safe drying conditions [12], [18]. The final stage includes experimental testing and performance evaluation. The system is tested under different temperature and loading conditions to observe drying rate, moisture reduction, energy use, and uniformity of drying. Controlled drying systems are reported to improve grain quality, storage life, and productivity when compared to conventional sun drying [19], [20].

S. No	Component Name	Specification	Quantity	Function
1	DC Gear Motor	12V, 60 RPM	1	Rotates drying drum
2	Cylindrical Rotor	Mild Steel Drum	1	Holds and mixes paddy
3	Hot Air Dryer	230V AC	1	Supplies heated air
4	Arduino Uno	ATmega328P	1	Main control unit
5	L293D Motor Driver	Dual H-Bridge IC	1	Controls motor speed/direction
6	Temperature Sensor	LM35 / DHT11	1	Measures chamber temperature
7	Relay Module	5V Single Channel	1	Heater ON/OFF control
8	Battery / Power Supply	12V DC	1	Supplies power to circuit
9	Frame Structure	Mild Steel	1	Supports complete system
10	Shaft and Coupling	Steel Material	1 Set	Transfers motor motion

S. No	Component Name	Specification	Quantity	Function
11	Air Duct / Pipe	PVC / Metal	1	Directs hot air flow
12	Discharge Mechanism	Mechanical Linkage	1	Removes dried paddy

Table.1. Specifications of Components

4. Experimentation

The experimental procedure was conducted to evaluate the performance of the paddy drying system with controlled air circulation under practical working conditions. The experiment mainly focused on moisture reduction, drying time, temperature control, airflow distribution, and grain quality after drying. Controlled drying methods are reported to improve efficiency and grain quality when compared with traditional sun drying practices [1], [7], [15].

S. No	Parameter	Value
1	Initial Moisture Content	20% – 25%
2	Final Moisture Content	12% – 14%
3	Motor Speed	60 RPM
4	Temperature Range	40°C – 70°C
5	Power Supply	12V DC / 230V AC
6	Drying Time	2 – 4 Hours
7	Paddy Load Capacity	3 – 5 kg

Table.2.Experimental Conditions

Freshly harvested paddy having an initial moisture content of 20% to 25% was collected and cleaned to remove dust, husk particles, and other impurities. A known quantity of paddy was loaded uniformly into the cylindrical drying chamber. Uniform loading is important for proper airflow and even drying of grains [3], [4].

S. No	Observation Parameter	Method
1	Temperature	Sensor Reading
2	Drying Time	Stopwatch
3	Moisture Reduction	Weight Comparison
4	Grain Quality	Visual Inspection
5	Drying Uniformity	Sample Observation

Table.3.Data Collection Parameters

After loading, the system power supply was switched ON. The 12V DC gear motor was started to rotate the drum continuously at 60 RPM, which ensured proper mixing of grains. At the same time, the 230V hot air dryer supplied heated air into the chamber. Continuous air circulation increased heat transfer and accelerated moisture removal from paddy grains [2], [14].

S. No	Parameter	Traditional Drying	Proposed Dryer
1	Drying Time	1–2 Days	2–4 Hours
2	Weather Dependency	High	Low
3	Drying Uniformity	Moderate	High
4	Labor Requirement	High	Low

S. No	Parameter	Traditional Drying	Proposed Dryer
5	Grain Quality	Moderate	Better

Table.4. Expected Performance Improvement

The internal chamber temperature was monitored using the temperature sensor connected to the Arduino Uno controller. The system maintained a drying temperature range of 40°C to 70°C. Whenever the temperature exceeded the preset limit, the heater was automatically turned OFF through the relay module. When the temperature dropped, the heater was switched ON again. Automatic control systems help in improving drying safety and energy efficiency [12], [18]. During operation, readings were recorded at regular intervals of 30 minutes. Parameters such as temperature, moisture loss, drying time, and grain condition were observed. The drying process was continued until the final moisture content reached approximately 12% to 14%, which is considered safe for storage [13], [20]. After completion, the heater and motor were switched OFF, and the dried paddy was discharged through the outlet mechanism. Final observations were made regarding grain color, cracks, and uniformity of drying. The results were compared with conventional drying methods to evaluate system improvement [19].

5. Results and Discussion

The developed paddy drying system with controlled air circulation was tested under different operating conditions to evaluate its drying performance, temperature control, moisture reduction, and grain quality. Experimental observations showed that the system operated successfully and provided uniform drying of paddy grains within a shorter duration when compared with conventional open sun drying methods [1], [7]. Fresh paddy with an initial moisture content of approximately 20% to 25% was dried to a final moisture content of 12% to 14%, which is suitable for safe storage and milling. The average drying time observed during testing was 2 to 4 hours, depending on the initial moisture level and quantity of paddy loaded into the chamber. This indicates a significant reduction in drying time when compared to traditional drying practices that may require one or more days under favorable weather conditions [15], [20].

The cylindrical rotating drum driven by the 12V DC gear motor provided continuous mixing of grains during operation. This rotation prevented local overheating and ensured that all grains received nearly equal exposure to hot air. As a result, moisture removal was more uniform throughout the chamber. Similar studies have reported that grain movement during drying improves heat transfer and reduces uneven drying [4], [5].

S. No	Parameter	Observed Result
1	Initial Moisture Content	20% – 25%
2	Final Moisture Content	12% – 14%
3	Drying Time	2 – 4 Hours
4	Temperature Range	40°C – 70°C
5	Motor Speed	60 RPM
6	Drying Uniformity	Good
7	Grain Quality	Improved

Table.5. Experimental Results

The hot air dryer maintained the chamber temperature within the desired range of 40°C to 70°C. The Arduino-based control system successfully monitored temperature conditions through the sensor and automatically switched the heater ON or OFF when required. This automatic regulation prevented excessive heating, reduced energy wastage, and protected grain quality. Previous investigations also concluded that controlled temperature drying improves efficiency and reduces grain damage [12], [18]. Visual inspection of dried paddy showed better color retention, lower grain cracking, and improved overall appearance when compared with uncontrolled drying methods. The final grains were cleaner and more suitable for storage. Proper moisture reduction also decreases the possibility of fungal growth and spoilage during storage [13], [19].

The results confirm that controlled air circulation combined with continuous grain rotation improves the drying process considerably. Uniform airflow inside the chamber accelerated moisture evaporation and reduced the total drying duration. The rotating mechanism further enhanced efficiency by exposing all grains evenly to heated air [3], [4], [14]. Automatic temperature control was one of the major advantages of the system. Without regulation, excessive heat can damage grains, reduce quality, and increase power consumption. The Arduino-based controller effectively maintained the required temperature, making the system safer and more economical [12], [18], [20]. The developed machine is especially useful for small and medium farmers because it reduces labor requirement, minimizes dependence on sunlight, and allows drying during unfavorable weather conditions. Although the prototype was developed on a small scale, the same concept can be extended for larger agricultural applications [7], [8], [19].

S. No	Validation Parameter	Expected Value	Obtained Value
1	Final Moisture	12% – 14%	12% – 14%
2	Drying Time	Less than Sun Drying	2 – 4 Hours
3	Temperature Control	40°C – 70°C	40°C – 70°C
4	Grain Quality	Minimal Damage	Improved
5	System Operation	Continuous	Stable

Table.6.Validation of results

The overall performance of the developed paddy dryer demonstrates that the system is efficient, reliable, and suitable for practical agricultural drying applications.

6. Conclusion

- The developed paddy drying system with controlled air circulation successfully reduced the moisture content of paddy from 20%–25% to 12%–14%, making it suitable for safe storage and further processing.
- The combination of hot air supply and continuous drum rotation provided uniform drying of grains and minimized uneven moisture distribution.
- The Arduino-based automatic control system effectively monitored temperature and controlled heater operation, ensuring safe and efficient drying conditions.
- The total drying time was significantly reduced to 2–4 hours when compared with conventional sun drying methods.
- The system improved grain quality by reducing chances of discoloration, cracking, fungal growth, and spoilage during storage.
- The developed unit reduced manual labor requirement and minimized dependence on weather conditions, making it more reliable for farmers.
- The machine was found to be compact, economical, and suitable for small and medium-scale agricultural applications.
- Overall, the project demonstrates that automated paddy drying technology can enhance post-harvest processing efficiency, improve productivity, and support modern smart farming practices.

7. Future scope of work

- The system can be upgraded by integrating moisture sensors, IoT monitoring, and mobile app control for real-time tracking and automatic operation.
- The drying unit can be scaled to a larger capacity model for commercial farms and rice mills with improved energy-efficient heating methods such as solar-assisted drying.
- Advanced control techniques using AI-based optimization and smart sensors can be implemented to achieve better temperature regulation, reduced power consumption, and higher drying efficiency.

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