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Drying of rice using an LPG-fueled rotary dryer

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Abstract

This study aims to analyze the performance of a rotary dryer in the grain drying process using an experimental research method. Drying was carried out at an operating temperature of 55 °C for 180 minutes, with temperature and grain moisture content monitored hourly. Observed parameters included hot plate temperature (T_P), drying chamber temperature (T_R), outlet air temperature (T_{out}), ambient temperature (T_L), and drying efficiency. The results showed that the drying system temperature was stable throughout the process, with TP ranging between 85–95 °C, T_R between 50–60 °C, and Tout slightly lower, indicating effective heat transfer from the heat source to the material. The grain moisture content decreased from 23% to 18.61% in the first hour, 14.01% in the second hour, and 11.45% in the third hour. The highest drying efficiency was achieved at 30% at the 60th minute, then decreased to 20% at the 180th minute as the material moisture content decreased and heat loss increased. Overall, the results of this study indicate that the rotary dryer is effective in reducing the moisture content of grain to a safe storage level (11–14%) with even heat distribution and good thermal efficiency. Therefore, this system has the potential to be applied to small- to medium-scale grain drying.

Keywords: Rotary dryer; Grain; Drying efficiency; Moisture content

1. Introduction

Rice drying is a crucial step in the rice production process , as it helps to reduce the moisture content of the grains to a safe level for storage and consumption [1]. The purpose of rice drying is to prevent the growth of mold and bacteria, which can lead to spoilage and reduce the quality of the rice [2]. Additionally, drying rice helps to improve its shelf life and maintain its nutritional value [3]. By properly drying rice, producers can ensure that their product meets quality standards and is safe for consumption. Properly dried rice also cooks more evenly and has a better texture, making it more appealing to consumers. Proper drying is essential in rice processing to prevent mold growth and maintain its quality. Sun drying is a traditional method that is cost-effective but can be time-consuming and weather-dependent [4]. Mechanical drying, on the other hand, is more efficient and can be controlled to ensure uniform drying. Infrared drying is a newer technology that can speed up the drying process and reduce energy consumption. Each method has its own advantages and challenges, but ultimately, the goal is to produce high-quality rice that is safe for consumption. Properly dried rice also helps in preventing the growth of bacteria and other harmful pathogens.

Rotary dryers are a common mechanical drying method used in the food industry, including for rice [5]. These dryers work by tumbling the rice in a rotating drum while hot air is blown through the material [6]. This helps to evenly distribute heat and moisture, resulting in faster and more efficient drying. One of the main advantages of rotary dryers is their ability to handle large quantities of rice at once, making them suitable for commercial-scale production. Additionally, the adjustable temperature and airflow settings allow for precise control over the drying process, ensuring consistent results. Overall, rotary dryers are a reliable and cost-effective solution for drying rice in bulk quantities. The

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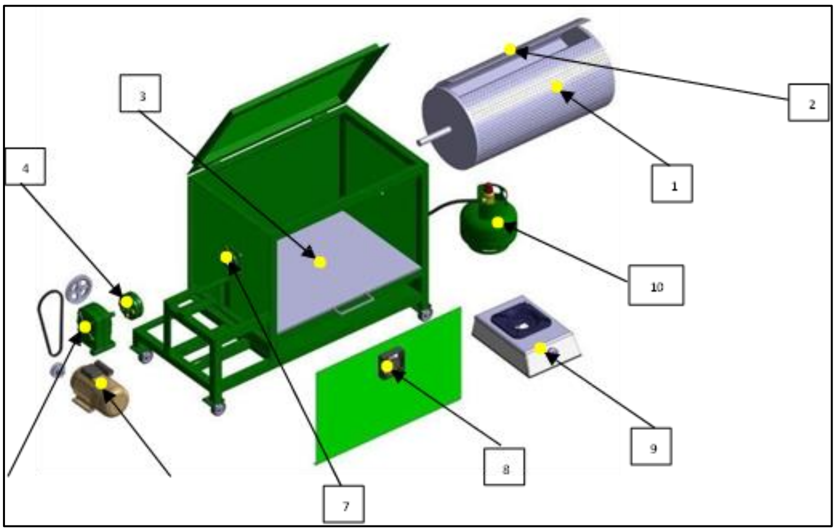
uniform drying process helps to maintain the quality and integrity of the rice, ensuring a consistent product that meets industry standards. With the ability to handle large volumes of rice at a time, rotary dryers are an essential piece of equipment for rice processing facilities looking to maximize efficiency and productivity. By utilizing adjustable settings for temperature and airflow, operators can customize the drying process to meet specific requirements, resulting in high-quality dried rice that is ready for packaging and distribution. The right drying technique will impact the nutritional value and flavor of rice. Researchers have explored various methods such as sun-drying, mechanical drying, and partial boiling to determine the most effective way to reduce moisture content while maintaining desired rice qualities [7]. Furthermore, studies have examined the impact of various drying methods on the physical characteristics of rice, such as color, texture, and cooking properties. Overall, the literature review indicates that rotary dryers offer a reliable and efficient solution for rice processing facilities seeking optimal drying results.

In terms of energy efficiency, cost-effectiveness, and the overall quality of the final product, several studies have also examined the environmental impact of this drying method, highlighting the importance of sustainable practices in the rice industry. By analyzing the findings from these various research efforts, rice producers can make informed decisions about the drying techniques that best suit their specific needs and priorities. Ultimately, the goal is to improve the efficiency and sustainability of rice processing operations while maintaining the high-quality standards expected by consumers. One of the key benefits of using a rotary dryer for rice drying is its ability to provide a consistent and uniform drying process. Unlike traditional sun drying methods, which are heavily reliant on weather conditions and can result in uneven drying, a rotary dryer offers greater control over the drying process [8]. This can lead to a more efficient and effective removal of moisture from the rice grains, resulting in a higher quality final product. Additionally, the use of a rotary dryer can help reduce the risk of mold growth and spoilage, ultimately prolonging the shelf life of the rice.

2. Research methods

The rotary dryer used in this study is a machine specifically designed for drying agricultural products such as rice. It consists of a large cylindrical drum that rotates on its axis, allowing for even distribution of heat and air throughout the drying chamber. This drum is equipped with internal racks that lift and rotate the rice grains, ensuring optimal exposure to the heated air. The dryer is also equipped with temperature and humidity sensors. Overall, this rotary dryer provides a reliable and efficient method of drying rice, resulting in a high-quality end product.

The research materials and tools include grain, LPG, household gas stove, K-type thermocouple, data logger, and rotary dryer. The rotary dryer uses iron plate, stainless steel plate, iron axle, iron box, and is equipped with exhaust fan, transmission system, insulating rubber, gearbox, trolley wheel, drying cylinder, and electric motor. The rotation of the drying cylinder is designed with a rotational speed of 10 rpm. The design of the rotary dryer for small scale is specifically adapted to the needs of small farmers in rural areas in Lombok. The rotary drying chamber has dimensions of 400 mm inner diameter of the cylinder and 800 mm long. The dryer is made to dry food ingredients in the form of grains, and in this study the test was carried out to dry corn kernels.



1.Rotary cylinder, 2.Cylinder cover, 3.Heating plate, 4.Gearbox connector, 5.Gearbox, 6.Electric motor, 7.Bearing, 8.Exhaust fan, 9.Gas stove, 10.LPG cylinder

Figure 1 Schematic of LPG energy rotary dryer

The efficiency of the rotary dryer in drying rice can be attributed to its ability to maintain consistent heat and airflow, ensuring that all grains are dried evenly. The internal flights within the drum help to prevent clumping and ensure that each grain is exposed to the hot air, resulting in a uniform drying process. Additionally, the temperature and moisture sensors allow for real-time monitoring and adjustments, ensuring that the rice is dried to the desired moisture content. Overall, the use of a rotary dryer for rice drying is a reliable and effective method that helps to produce high-quality rice for consumption. Factors that affect the performance of a rotary dryer include the type of fuel used for heating, the drum rotation speed, and the ambient humidity level. Proper maintenance and regular cleaning of the dryer are also crucial to maximizing its efficiency. Furthermore, the dryer's size and design can impact its performance, with larger dryers typically being more efficient at drying large quantities of rice. Proper airflow management and heat distribution within the dryer are crucial to ensuring consistent and thorough drying of the grain. By considering these factors, operators can optimize the drying process and efficiently produce high-quality rice.

3. Results and discussion

The relationship between grain moisture content and drying time shows a nonlinear pattern of decreasing moisture content over time. At the beginning of the drying process, the decrease in moisture content occurs rapidly because free water on the grain surface evaporates easily due to the high vapor pressure difference between the drying air and the grain surface. However, as time passes, the drying rate decreases because the remaining water is in the internal tissue of the grain and must diffuse to the surface before it can evaporate. This process is known as the decreasing rate period, which is the dominant stage in grain drying [9]. A similar pattern was also obtained in this study, as shown in Figure 2.

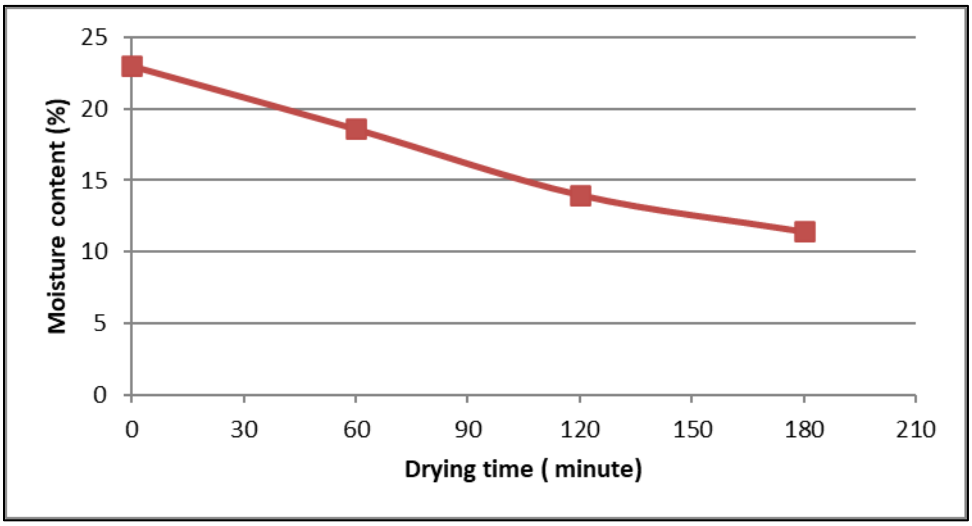


Figure 2 Drying time on grain moisture content

The rice sample (initial MC value of 23%) lost 4.39, 4.60, and 2.56 percentage points in the first, second, and third hours at 55 °C, respectively, representing absolute decreases of 4.39%, 4.60%, and 2.56%, respectively. Relatively, these decreases equate to ~19.1% of the initial moisture content removed in the first hour, ~24.7% of the current moisture content in the second hour, and ~18.3% in the third hour. These figures indicate a rapid initial drying phase, followed by a significant slowdown in the third hour, consistent with a transition to a period of reduced drying rate where internal water diffusion controls the drying rate [10].

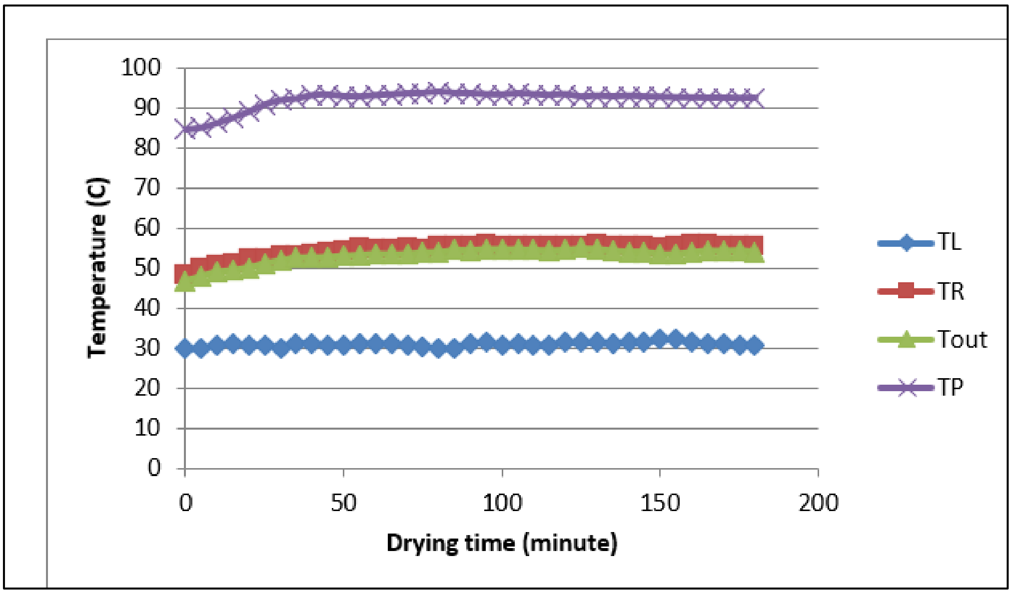


Figure 3 Temperature distribution in a rotary dryer

The figure shows the temperature changes in a grain drying system over 180 minutes at an operating temperature of 55°C. The graph shows that the hot plate temperature (T_P) has the highest value, ranging from 85–95°C, indicating the heating element's primary function as a source of thermal energy to evaporate water from the grain. The drying chamber temperature (T_R) is in the range of 50–60°C and remains relatively stable after the first 30 minutes, indicating that the system has reached a steady state, where the heat energy from the plate is evenly distributed throughout the drying chamber. Overall, this graph illustrates that the drying system operates stably at 55°C, with good heat distribution and thermal conditions that support efficient grain drying.

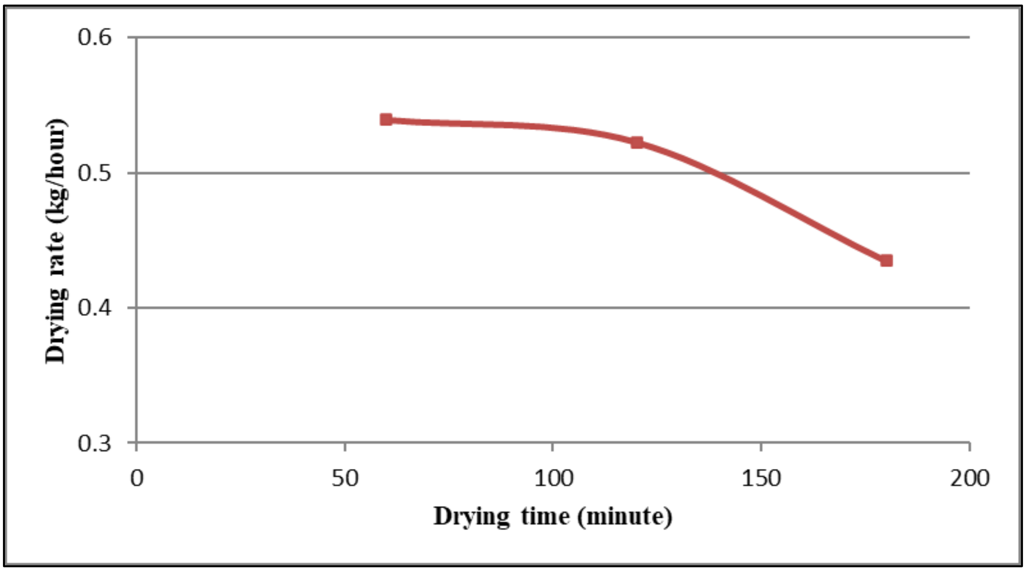


Figure 4 Draying time Vs draying rate

Figure 4 shows the relationship between drying time and drying rate of grain at 55°C using a rotary dryer. It can be seen that the drying rate decreases over time. At the beginning of the process, the drying rate is relatively high because the free water content on the grain surface is still high, resulting in rapid evaporation. However, as time passes, the remaining water becomes increasingly difficult to remove because it is tightly bound within the grain. As a result, the drying mechanism is dominated by water vapor diffusion from the interior to the surface, causing the drying rate to decrease. This phenomenon indicates that the process is experiencing a period of decreasing drying rate, which is common in the drying of agricultural products. The significant decrease in drying rate after 120 minutes indicates a decrease in drying efficiency in the final phase. This condition indicates the need for temperature and air circulation control to make the process more efficient without reducing grain quality.

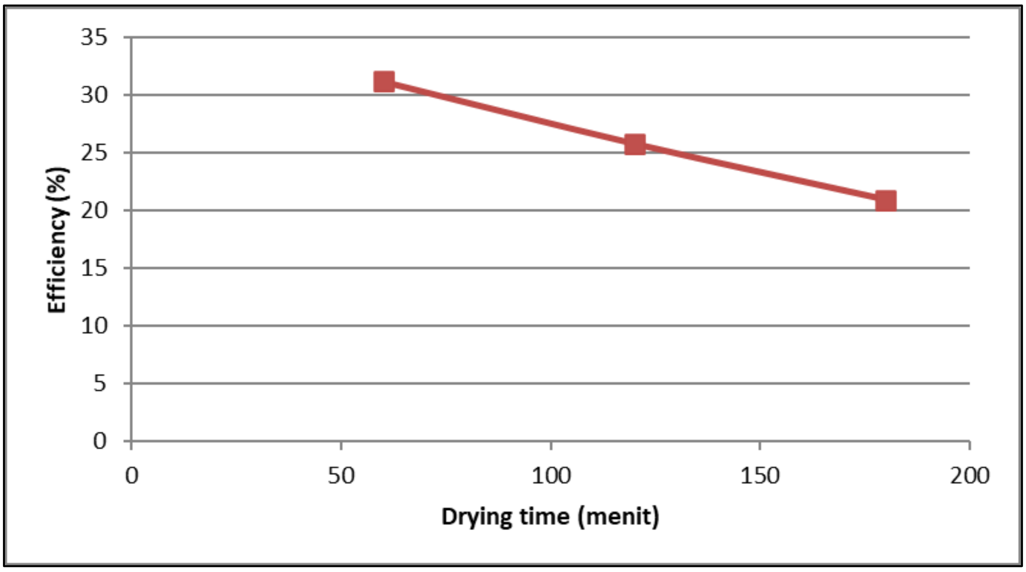


Figure 5 Drying time Vs efficiency

The graph shows the relationship between drying efficiency (%) and drying time (minutes) at an operating temperature of 55°C. The graph shows that drying efficiency decreases with time, from approximately 30% at 60 minutes, to 25% at 120 minutes, and then again to approximately 20% at 180 minutes. This decrease in efficiency occurs because the moisture content of the grain is still high at the beginning of drying, resulting in a large vapor pressure difference between the grain surface and the drying air, resulting in a high evaporation rate and optimal energy efficiency. However, after most of the free water has evaporated, the remaining water remains within the grain's capillary structure and requires more time and energy to move to the surface and evaporate. Consequently, more of the supplied heat energy is used to maintain the system temperature than to evaporate the water, resulting in decreased efficiency [11]. This phenomenon aligns with the principle of a falling rate period, which is common in drying agricultural materials, including grain. Furthermore, heat loss through the dryer walls and exhaust air also contributes to the decline in efficiency over time.

4. Conclusion

Based on the results of the study of grain drying using a rotary dryer at an operating temperature of 55°C for 180 minutes, it can be concluded that the drying process was effective but showed the general characteristics of drying agricultural materials, namely a significant decrease in moisture content at the beginning of the process and a decrease in thermal efficiency with increasing time. This pattern indicates that the drying rate was high in the initial stage due to the evaporation of free water on the grain surface, then decreased in the later stages when the process was controlled by the internal diffusion of water within the grain. The temperature of the heating plate (TP) reached 85–95°C as the main heat source, while the temperature of the drying chamber (TR) was in the range of 50–60°C and remained relatively constant after reaching steady state. Drying efficiency decreased from approximately 30% at the 60th minute to 20% at the 180th minute. This decrease was caused by the reduction in the material's moisture content and the increase in heat loss to the environment over time. Overall, the rotary dryer, operating at 55°C, reduced the moisture content of grain to a safe storage level (around 11–14%), maintaining good drying chamber temperature stability and adequate thermal efficiency. Therefore, this system is effective for small- to medium-scale grain drying, with an optimal drying time of around 2–3 hours.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed

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