Engineering and Technology Journal e-ISSN: 2456-3358

Volume 11 Issue 07 July-2026, Page No.-11015-11019

DOI: 10.47191/etj/v11i07.27, I.F. – 8.595

The Effect of Cylinder Rotation Speed on Temperature Distribution in Rotary Dryer

Rudy Sutanto[1], Sujita[2]

[1,2]Departmen of Mechanical Engineering, Faculty of Engineering, Mataram University, Mataram, Indonesia.

ABSTRACT: The thermal conditions inside a rotary dryer are influenced by the cylinder rotation speed, which determines the distribution of hot air during the drying process. These differences in thermal conditions affect the drying chamber's ability to utilize available heat. This study evaluated the effect of varying cylinder rotation speeds on the temperature profile and heat utilization effectiveness in the corn drying process. Tests were conducted for 6 hours using three variations in cylinder rotation speeds. The inlet air temperature, drying chamber temperature, and outlet air temperature were recorded every 30 minutes using a thermocouple. Heat utilization effectiveness was determined based on the relationship between the inlet air temperature, drying chamber temperature, and ambient temperature. During the drying process, the inlet air temperature was in the range of 70.2–73.5°C, while the drying chamber temperature and outlet air temperature changed as the drying process progressed. Heat utilization effectiveness increased from approximately 80% at the beginning of the drying process to approximately 90% at the end of the process. Different cylinder rotation speeds resulted in different temperature profile characteristics, followed by changes in heat utilization effectiveness in the drying chamber. Higher rotation speeds were able to maintain more stable thermal conditions, resulting in better heat utilization. These findings indicate that adjusting the cylinder rotation speed is an important parameter for improving the thermal performance of a rotary dryer in the corn drying process.

KEYWORDS: rotary dryer, corn, cylinder rotation speed, temperature profile, heat utilization effectiveness

I. INTRODUCTION

Corn (Zea mays L.) is a strategic food commodity widely used as a raw material for the food, animal feed, and bioenergy industries. After harvest, corn generally still has a relatively high water content, requiring immediate drying to reduce the risk of damage during storage. Drying aims to reduce the water content to a safe level, thereby suppressing microbial activity, respiration, and chemical reactions that can degrade product quality. Traditional drying methods utilizing sunlight are still widely used due to their low operational costs, but they are highly affected by weather conditions, require long drying times, and often produce uneven moisture content. Therefore, the use of mechanical dryers is a more effective alternative because they provide more controlled drying conditions, speed up the process, and produce more consistent product quality [1], [2], [5].

One mechanical dryer widely used for agricultural commodities is the rotary dryer. This system works by rotating a cylinder, continuously stirring the material and gaining more intensive contact with hot air. This mechanism enhances heat and mass transfer, resulting in a better drying rate than static dryers. Rotary dryer performance is influenced by various operating parameters, including drying air temperature, air flow rate, material characteristics, lifter design, and cylinder rotation speed. Changes in any of these parameters will affect the temperature distribution in the drying chamber, which in turn determines the system's ability to utilize heat energy during the drying process [2], [3], [6]–[8].

Various studies have been conducted to improve the performance of rotary dryers. Alit et al. [2] reported that utilizing rice husk biomass as an energy source can improve the thermal performance of corn dryers by improving the heating system. Subsequent research demonstrated that integrating a biomass heat source into a rotary dryer provides better temperature distribution than conventional systems [3]. Li et al. [4] stated that drying air temperature regulation influences the drying characteristics of corn on an industrial scale, while Baidhe et al. [5] showed that thermal conditions during the drying process affect drying kinetics, heat transfer, mass transfer, and the thermodynamic properties of the material. Furthermore, research on heat transfer mechanisms within a rotating cylinder has been developed using numerical and experimental approaches to explain heat distribution during the drying process [7], [9], [15]. These findings confirm that thermal conditions are a key factor determining drying system performance.

Although research on rotary dryers has progressed significantly, most of it still focuses on analyzing energy consumption, modeling drying kinetics, heat transfer characteristics, or developing mathematical models. Studies directly linking cylinder rotation speed to temperature profiles and the effectiveness of heat utilization within the drying chamber are still relatively limited. In fact, temperature distribution is an important indicator of how heat energy is utilized during the process. Evaluation of the inlet air temperature, drying chamber temperature, and outlet air temperature can provide information on the stability of thermal conditions and serve as a basis for evaluating the effectiveness of heat utilization in rotary dryers. This information is necessary to determine operating parameters capable of producing a more stable, effective, and energy-efficient drying process [4], [6], [9]–[13].

Based on these conditions, this study aims to analyze the effect of cylinder rotation speed on the temperature profile and heat utilization effectiveness in rotary dryers during the corn drying process. The temperature profile is analyzed based on changes in inlet air temperature, drying chamber temperature, and outlet air temperature during the drying process, while heat utilization effectiveness is used to evaluate the drying chamber's ability to maintain available heat energy. The results of this study are expected to contribute to the development of rotary dryer operations, particularly in determining the cylinder rotation speed that can produce more stable thermal conditions, thus making the corn drying process more effective.

II. RESEARCH METHODS

This study used an experimental method to analyze the effect of cylinder rotation speed on the temperature profile and the effectiveness of heat utilization in the corn drying process using a rotary dryer. The test was conducted at the Mechanical Engineering Laboratory of the University of Mataram using a horizontal cylinder type rotary dryer equipped with an LPG-fueled heating system, a blower as a hot air supplier, an electric motor, a gear reducer, and a transmission system that functions to regulate the cylinder rotation speed. The research equipment schematic is shown in Figure 1.

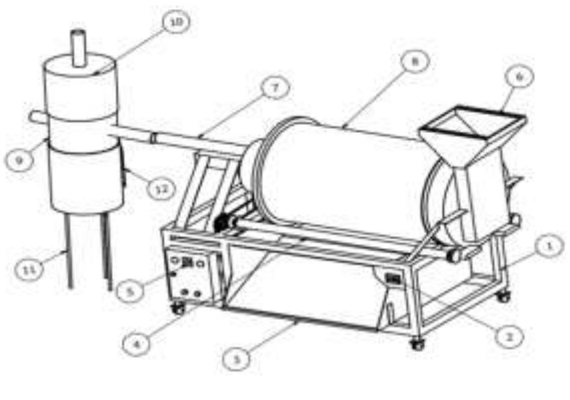

Figure 1. Research tool scheme, 1. Frame, 2. temperature control, 3. coffee bean ejector, 4. roll support, 5. motor rotation control, 6. turmeric slice input place, 7. hot air duct, 8. drying cylinder, 9. heat exchanger, 10. burner, 11. burner foot, 12. Burner door

Shelled corn was used as the test material with an initial moisture content corresponding to post-harvest conditions. Before the drying process began, the corn was weighed using a digital scale to determine its initial mass, then loaded into the drying chamber. Hot air was generated by an LPG stove and channeled into the drying chamber using a blower. Throughout the process, the cylinder was rotated continuously, agitating the corn and directly contacting it with the hot air.

The independent variable in this study was the cylinder rotation speed, which was 6 rpm, 9 rpm, and 12 rpm. The dependent variables included the inlet air temperature, drying chamber temperature, outlet air temperature, temperature gradient, and heat utilization effectiveness. Ambient temperature was also measured as a supporting parameter in calculating heat utilization effectiveness. All temperatures were measured using a K-type thermocouple connected to a data logger. Data were collected every 30 minutes for 6 hours of drying.

Temperature profile analysis was performed by comparing changes in inlet air temperature, drying chamber temperature, and outlet air temperature at each variation in cylinder rotation speed. Furthermore, the temperature gradient was calculated to determine the temperature difference between the inlet air and the drying chamber using Equation (1).

$$\Delta T = T_{in} - T_r \quad (1)$$

Where ΔT = temperature gradient (°C), Tin = inlet air temperature (°C), Tr = drying chamber temperature (°C).

The heat utilization effectiveness is calculated to describe the drying chamber's ability to utilize available heat energy. The calculation is performed using Equation (2).

$$\eta_h = \frac{T_r - T_a}{T_{in} - T_a} \quad (2)$$

Where ηh = heat utilization effectiveness (%), Tr = drying chamber temperature (°C), Tin = inlet air temperature (°C), Ta = ambient temperature (°C).

The measurement data were processed using Microsoft Excel to obtain average values and graph temperature changes, temperature gradients, and heat utilization effectiveness at each cylinder rotation speed variation. A descriptive-comparative analysis was then performed to compare the thermal characteristics produced at each cylinder rotation speed and identify the operating conditions that provided the best heat utilization during the drying process.

III.RESULTS AND DISCUSSION

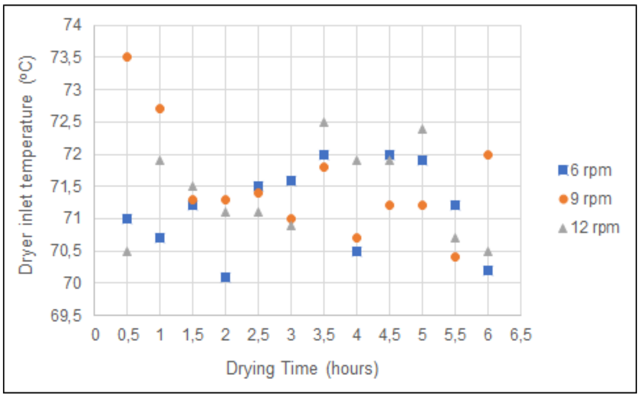

Figure 2. Graph of the relationship between drying time and dryer inlet temperature

Figure 2 shows the change in inlet air temperature during the corn drying process at cylinder rotation speeds of 6 rpm, 9 rpm, and 12 rpm. The inlet air temperature was in the range of 70.1–73.5 °C with relatively small fluctuations during the six hours of drying. At 9 rpm, the initial temperature was recorded as the highest, namely 73.5 °C, while at 6 rpm and 12 rpm, the temperature tended to be more stable in the range of 70–72.5 °C. The difference in inlet air temperature at the three rotation variations did not show a significant pattern. This indicates that the inlet air temperature is more influenced by the performance of the heating system and the air flow rate than the cylinder rotation speed. Thus, variations in cylinder rotation do not have a direct effect on the temperature of the air entering the drying chamber, but rather influence the heat distribution process during drying [2], [4].

The results of this study are in line with Alit et al. [2] which states that the inlet air temperature in a rotary dryer is relatively stable as long as the heating system works under constant operating conditions. Li et al. [4] also reported that the stability of the inlet air temperature is an important factor in maintaining the heat transfer process so that drying takes place more uniformly.

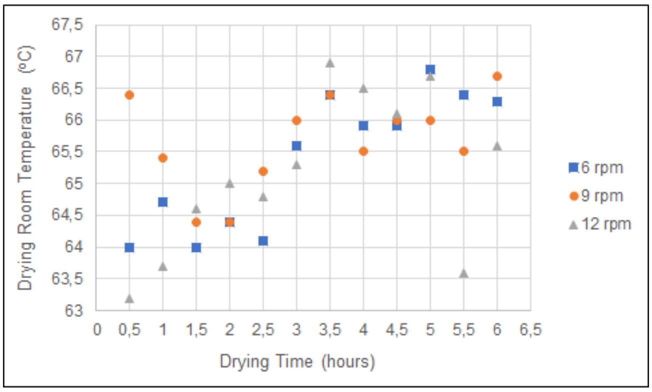

Figure 3. Graph of the relationship between drying time and drying room temperature

Figure 3 shows the changes in drying room temperature during the corn drying process at cylinder speeds of 6 rpm, 9 rpm and 12 rpm. The drying chamber temperature ranges from 63.2–66.9 °C and generally increases with increasing drying time until it reaches a relatively stable level at the end of the process. In the three cylinder rotation variations, the drying chamber temperature showed almost identical trends, increasing gradually from the beginning to the middle of the drying process. The highest temperature of 66.9 °C was reached at 12 rpm in about 3.5 hours, while the temperatures at 6 rpm and 9 rpm reached a maximum of about 66.8 °C and 66.7 °C, respectively. This shows that increasing the cylinder rotation speed accelerates the distribution of hot air in the drying chamber, resulting in a more even temperature distribution [2], [7].

Overall, the drying chamber temperature at 12 rpm tends to be slightly higher than at 6 rpm and 9 rpm. This shows that higher cylinder rotation increases the intensity of mixing corn with hot air so that heat transfer occurs more effectively. These results are in line with research by Alit et al. [2] and Xie et al. [7], which states that the flow and mixing characteristics in a rotary dryer affect the temperature distribution and heat transfer performance during the drying process.

Figure 4 shows changes in exhaust air temperature during the corn drying process at cylinder rotation speeds of 6 rpm, 9 rpm and 12 rpm. The outlet air temperature was in the range of 56.3–63.3 °C and generally increased with increasing drying time. This increase in temperature indicates that the air in the drying chamber is getting hotter until the system reaches a relatively stable condition.

At 12 rpm rotation, the exit air temperature tends to be higher than at 6 rpm and 9 rpm rotation, with the maximum temperature reaching around 63.3 °C at the 5th hour. Meanwhile, the maximum temperatures at 6 rpm and 9 rpm are around 62.5 °C and 62.4 °C respectively. This condition shows that increasing the cylinder rotation speed improves the mixing of materials with hot air so that the heat distribution in the drying chamber becomes more even and increases the temperature of the air leaving the system [2], [7]. Overall, the increase in outlet air temperature indicates that the heat transfer process is proceeding well during drying. The temperature difference between the rotation variations is relatively small, but the 12 rpm rotation tends to have a higher exit air temperature. These results are in line with research by Alit et al. [2] and Rocha et al. [9], which states that the air flow characteristics and mixing intensity in a rotary dryer influence the heat distribution and thermal performance during the drying process.

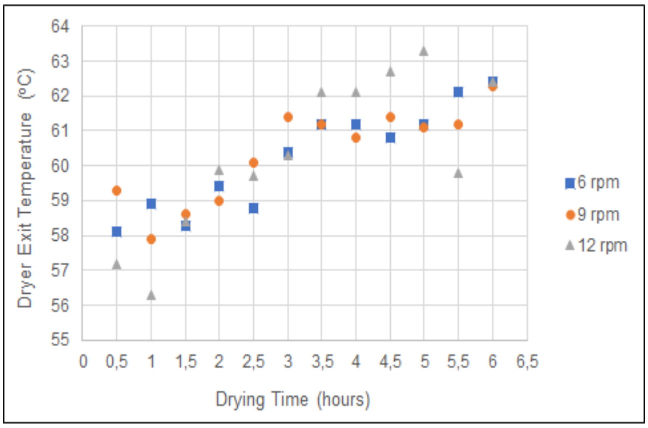

Figure 4. Graph of the relationship between drying time and dryer exit temperature

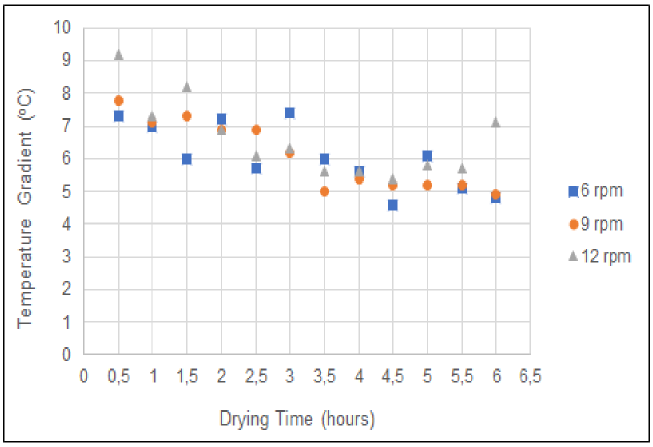

Figure 5. Graph of the relationship between drying time and temperature gradient

Figure 5 shows the change in temperature gradient between the inlet air and the drying chamber during the corn drying process. In general, the temperature gradient decreases as drying time increases, from about 7.0–9.2 °C at the beginning of the process to 4.8–7.1 °C at the end of drying. This decrease indicates that the drying room temperature is getting closer to the inlet air temperature so that the heat distribution in the rotary dryer becomes more even. At 12 rpm rotation, the temperature gradient tends to be higher at the beginning of drying compared to 6 rpm and 9 rpm rotation. However, as time goes by, the difference becomes smaller as the temperature of the drying chamber increases and the system reaches a more stable condition. This shows that the heat entering the drying chamber is increasingly utilized during the process [2], [7]. The results of this study are in line with Alit et al. [2] and Rocha et al. [9], which states that good heat distribution in a rotary dryer supports a more effective drying process and produces more stable thermal conditions.

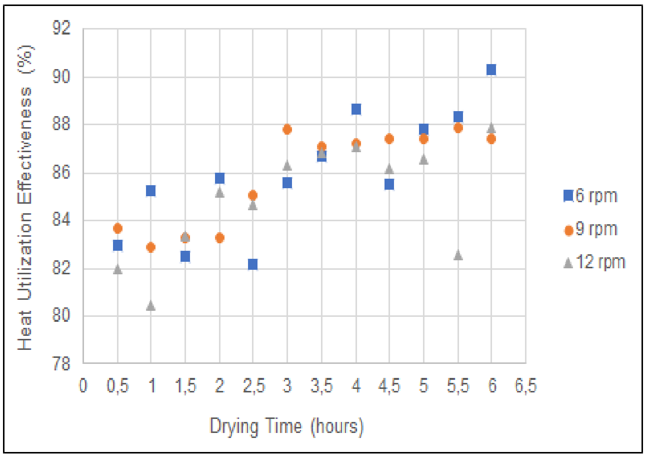

Figure 6. Graph of the relationship between drying time and the effectiveness of heat utilization

Figure 6 shows changes in the effectiveness of heat utilization during the corn drying process at cylinder rotation speeds of 6 rpm, 9 rpm and 12 rpm. In general, the effectiveness of summer utilization increases with increasing drying time. The effectiveness value is in the range of 80.4–90.2%, which indicates that most of the incoming heat energy has been utilized in the drying chamber. 6 rpm rotation produces the highest heat utilization effectiveness, namely around 90.2% at the end of the drying process. Meanwhile, the 9 rpm rotation shows a relatively stable value in the range of 83.0–87.8%, while the 12 rpm rotation fluctuates with a maximum value of around 87.9%. This difference shows that the rotation speed of the cylinder influences the ability of the drying chamber to utilize heat energy during the drying process. The results of this study are in line with Alit et al. [2] and Li et al. [4], which states that the effectiveness of heat utilization is influenced by the temperature distribution and operating conditions of the rotary dryer. The better the heat distribution in the drying chamber, the higher the system's ability to utilize available heat energy.

CONCLUSIONS

This research shows that the cylinder rotation speed influences the temperature profile and effectiveness of heat utilization in the rotary dryer during the corn drying process. The inlet air temperature is relatively stable in the range of 70.1–73.5 °C, while the drying room temperature and outlet air temperature tend to increase with increasing drying time until they reach a stable condition. The temperature gradient between the incoming air and the drying chamber decreases during the drying process, which shows that the heat distribution in the drying chamber becomes more even. The effectiveness of heat utilization is in the range of 80.4–90.2% and generally increases during the drying process, with the highest value obtained at 6 rpm, namely around 90.2%. The results of this research indicate that variations in cylinder rotation speed influence the thermal characteristics of the rotary dryer and the system's ability to utilize heat energy during the corn drying process.

REFERENCES

1. Alit, I. B., & Susana, I. G. B. (2025). Thermal Performance of LPG Stove as Heat Source of Rotary Dryer for Drying Corn for Small Farmers. Jurnal Teknik Pertanian Lampung, 14(2), 537–546. https://doi.org/10.23960/jtep-l.v14i2.537-546
2. Alit, I. B., Susana, I. G. B., & Mara, I. M. (2020). Utilization of rice husk biomass in the conventional corn dryer based on the heat exchanger pipes diameter. Case Studies in Thermal Engineering, 22, 100764. https://doi.org/10.1016/j.csite.2020.100764
3. Susana, I. G. B., Alit, I. B., & Okariawan, I. D. K. (2023). Rice husk energy rotary dryer experiment for improved solar drying thermal performance on cherry coffee. Case Studies in Thermal Engineering, 41, 102616. https://doi.org/10.1016/j.csite.2022.102616
4. Li, B., Zeng, Z., Zhang, X., & Zhang, Y. (2021). Study on the Variable-Temperature Drying Process of Corn Drying in an Industrial Corn-Drying System Equipped with a Self-Adaptive Control Heat Exchanger. Applied Sciences, 11(6), 2772. https://doi.org/10.3390/app11062772
5. Baidhe, E., Clementson, C. L., Hellevang, K., & Zhulu, L. (2025). Comprehensive Analysis of Drying Kinetics, Heat and Mass Transfer, and Thermodynamic Properties in High-Temperature Drying of High-Moisture Corn. Journal of Food Process Engineering, 48(6), e70159. https://doi.org/10.1111/jfpe.70159
6. Rodviboonchai, P., & Soponronnarit, S. (1992). Corn Drying by a Rotary Dryer: A Mathematical Model and Drying Strategy. Agriculture and Natural Resources, 26(1), 50–59.
7. Xie, Q., Chen, Z., Mao, Y., Chen, G., & Shen, W. (2018). Case studies of heat conduction in rotary drums with L-shaped lifters via DEM. Case Studies in Thermal Engineering, 11, 145–152. https://doi.org/10.1016/j.csite.2018.02.001
8. Trojosky, M. (2019). Rotary drums for efficient drying and cooling. Drying Technology, 37(5), 632–651. https://doi.org/10.1080/07373937.2018.1552597
9. G.F.M.V. Souza, P.S. Avendaño, M.C.C. Francisquetti, F.R.C. Ferreira, C.R. Duarte, M.A.S. Barrozo. (2020). Modeling of heat and mass transfer in a non-conventional rotary dryer. Applied Thermal Engineering, 182, 116118. https://doi.org/10.1016/j.applthermaleng.2020.116118
10. Incropera, F. P., Bergman, T. L., Lavine, A. S., & DeWitt, D. P. (2017). Fundamentals of Heat and Mass Transfer (8th ed.). John Wiley & Sons.
11. Çengel, Y. A., & Ghajar, A. J. (2020). Heat and Mass Transfer: Fundamentals and Applications (6th ed.). McGraw-Hill.
12. Mujumdar, A. S. (2014). Handbook of Industrial Drying (4th ed.). CRC Press.
13. Geankoplis, C. J., Hersel, A. A., & Lepek, D. H. (2018). Transport Processes and Separation Process Principles (5th ed.). Pearson.
14. Habibi, M. A. F., Sutanto, R., & Wirawan, M. (2026). Effect of Cylinder Rotation Speed on Corn Drying Characteristics in a Rotary Dryer. Journal of Mechanical Engineering, Science, and Innovation, 6(1).
15. Defraeye, T. (2014). Advanced computational modelling for drying processes—A review. Applied Energy, 131, 323–344.