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Evaluation of the temperature of the rotary dryer with LPG fuel in drying cherry coffee

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ABSTRACT

Utilization of rotary dryers with liquefied petroleum gas (LPG) energy sources as an alternative to solar drying, which is highly dependent on the weather. This dryer is applied to small farmers to dry cherry coffee. The results of the study showed that the drying temperature reached an average of 63.92°C to dry a sample of 10 kg of cherry coffee. From testing, this sample still produced a reasonably high outlet temperature of the drying chamber, which was an average of 62.07°C. From this condition, it is possible to increase the amount of cherry coffee to be dried, and further testing is needed. LPG-based rotary dryers are very easy for small farmers. The drying process can be carried out all the time because it does not depend on the weather. In addition, LPG in Indonesia for small farmers is still subsidized, so it is economically affordable. The shorter drying time than solar drying allows small farmers to carry out their production process sustainably. In 20 hours of testing, it was able to reduce the moisture content from 62.84% to 9.95%.

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1. INTRODUCTION

Cherry coffee, or whole coffee with its skin, is a harvest product that is picked from the tree. Post-harvest from cherry coffee requires further processing so that it is ready to be served or drunk. Cherry coffee becomes coffee in the form of green beans by separating the coffee beans from the skin. The process is through separation when the cherry coffee is still wet or dried first. The standard method is drying cherry coffee before making it into green beans. Green bean coffee is raw coffee beans that are generally green and have not been roasted. Small farmers typically dry naturally, namely by drying in the sun. Natural drying provides a non-optimal temperature and a relatively long time because it is very dependent on the weather. To increase the temperature and shorten the time, it can be done through a rotary dryer with liquefied petroleum gas (LPG) fuel.

The application of rotary dryers with LPG energy sources is in participation with the role of its users, in this case, small farmers. The use of LPG as an energy source for rotary dryers is due to subsidies from the Indonesian Government for small farmers. The use of rotary dryers provides advantages in the form of increased drying rates, continuous drying throughout the day, and better-quality dried products (Kabeel et al., 2016). Compared to solar drying, the use of dryers can provide a shorter time. Based on research by Bawa Susana et al. (2023), drying coffee beans to reach a moisture content of 13.14%, which is done naturally, namely drying in the sun, takes 16 days. The length of drying has an impact on the level of farmer productivity after harvest.

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According to Paristiawan et al. (2022), the problems that arise from the sun-drying process carried out in the open are insufficient or excessive drying, exposure to animals, dust, and rain. Sun drying in the open impacts workers, namely exposure to heat with high temperatures. Higher temperatures, relatively high workloads, lack of concentration, and fatigue decrease productivity, increasing the risk of injury (Bawa Susana, 2018; Oshwiki, 2023). Losses incurred in the agricultural sector due to inappropriate drying equipment that have an impact on high energy consumption contribute around 60% of the energy consumption of the entire production process as occurs in tobacco (Nguimdo and Noumegnie, 2020; Li et al., 2020; Li et al., 2022). To minimize losses for farmers, especially small farmers, artificial drying equipment with either LPG or biomass energy is needed. The use of this energy source is greatly influenced by the role of small farmers as users. Farmer participation is required so that the drying equipment and energy source utilization are in accordance with needs. Participation from users is known as a participatory approach as the most effective way to redesign manual tasks, benefit the procurement of work equipment, and ease the physical workload (Sormunen et al., 2022; Burgess-Limerick, 2018). The application of a participatory approach produces several models of drying equipment according to the needs of small farmers as users. As in the research of Alit and Bawa Susana (2024), who designed a dryer utilizing rice husks through a heat exchanger for one furnace for small farmers to dry bananas, however, this model of dryer is not yet suitable for drying cherry coffee, so a dryer is needed that suits the needs of farmers. Cherry coffee in the form of beans will be easier to dry with a cylindrical and rotating dryer with LPG energy because this energy is still subsidized for small farmers. Cylindrical and rotating dryers are called rotary dryers, and LPG is used as an energy source to overcome the shortcomings of solar and biomass drying. This dryer model rotates continuously and is very suitable for granular food materials such as grains. Rotary cylinders or rotary drums are widely applied in mixing, cooling, heating, and drying processes for granular materials (Ettahi et al., 2022; Trojosky, 2019; Xie et al., 2018). Rotary dryers are applied to small farmers because of their affordable cost and easy operation, and they produce uniforms dry. Rotary dryers have low maintenance costs and consume 15 to 30% less specific energy (Giudice et al., 2019).

The use of rotary dryers with LPG energy for small farmers provides convenience, namely, not depending on the weather, so drying can be done at any time. In addition, the product is not contaminated by smoke or LPG fuel gas because the rotary dryer uses an indirect drying method. The dryer is designed for testing in drying wet coffee beans (cherry/berry), namely the harvest of coffee berries with a moisture content ranging from 60 to 65%. Coffee that is dried based on post-harvest handling guidelines for coffee, namely coffee beans, is still protected by the skin of the fruit flesh, mucus layer, horn skin and epidermis in dry conditions (Ministry of Agriculture of the Republic of Indonesia, 2012). The drying process is carried out as an effort to reduce moisture content to a specific limit. Drying uses an indirect heating system to prevent smoke contamination from burning fuel to the surface or into the coffee beans. This dryer model is used to produce a uniform drying temperature and is easy for small farmers to operate.

2. RESEARCH METHODS

Research on rotary dryer applications to produce even temperatures in a drying chamber so that the dried grains can dry evenly. Drying equipment is based on the needs of small farmers. Tools and materials consist of LPG, household gas stoves, type K thermocouples, data loggers, rotary cylinders, iron plates, square iron, stainless steel plates, stainless steel pipes, axle iron, 1 Hp dynamo, gearbox, insulating rubber, trolley wheels, transmission systems, drying cylinders, one exhaust fan, and cherry coffee.

The design of the dryer is compact, with a drying chamber consisting of parts in the form of a circular cylinder and a noncircular cylinder. The non-circular cylinder outside the rotary cylinder is a fixed cylinder equipped with one exhaust fan. The combustion chamber is made flexible; namely, it can be replaced as a container for dried products. Cherry coffee is dried in a rotary cylinder and rotates following the rotation of the rotary cylinder. The cylinder rotates with an electric motor and is assisted by a gear transmission. The cover on the rotary cylinder functions to facilitate the removal and insertion of cherry coffee. The walls of the rotary cylinder are made with small holes so that the inner surface of the cylinder is not smooth. The tube is internally rough with a surface to develop a more effective heat exchanger, and the heat transfer rate is better than a smooth tube (Oyewola et al., 2023; Boonloi and Jedsadaratanachai, 2021). The cherry coffee sample tested was 10 kg. Exhaust fan with a constant speed of 2.9 m / s. Testing the dryer with cherry coffee samples, as shown in Figure 1 and Figure 2.

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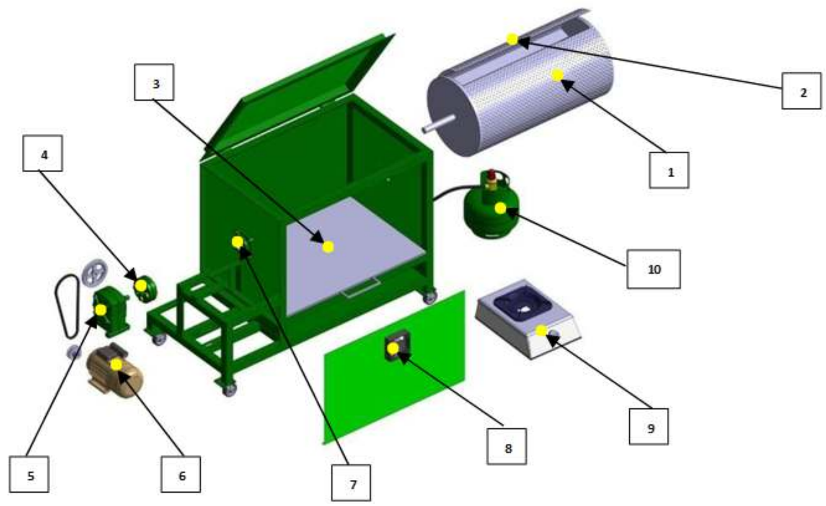

Figure 1. Schematic of LPG energy rotary dryer. 1. Rotary cylinder, 2. Rotary cylinder cover, 3. Heating plate, 4. Gearbox connector, 5. Gearbox, 6. Electric motor, 7. Bearing, 8. Exhaust fan, 9. Gas stove, 10. LPG cylinder

(a) (b)

Figure 2. Experimental equipment, a) rotary dryer, b) testing of cherry coffee samples

The study was conducted to analyse the performance of a rotary dryer with LPG as an energy source for drying cherry coffee. The analysis was carried out based on the amount of drying heat, drying rate, and drying efficiency. Data were measured, such as ambient temperature, bottom plate, drying chamber, outlet temperature at the exhaust fan, initial or total mass and dry mass of cherry coffee. The moisture content K_a (%) is calculated based on the total mass of coffee cherry, m_t (kg) and the dry mass of coffee cherry, m_k (kg). The initial moisture content test of the material is carried out by heating the material until there is no change in weight so that the moisture content in the material is used up (dry mass of the material). The moisture content test of the coffee cherry is carried out by heating 200 grams of sample for 13 hours at a temperature of 105-110^{o}C to obtain the dry mass, m_k.

$$K_a = \frac{m_t - m_k}{m_t} x\ 100\% \quad (1)$$

The total heat used in the drying process is Q (kJ), as in equation (2).

$$Q - Q_1 + Q_2 + Q_3 \quad (2)$$

Q_1 is the sensible heat of the material (kJ). Q_2 is the heat to evaporate the water of the material (kJ) (Hamdani et al., 2018; Çengel et al., 2019). Q_1 is obtained based on the mass, specific heat, and temperature of the material, as presented in equation (3).

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$$Q_1 = m_t C_{pb} (T_r \quad T_a) \tag{3}$$

m_t is the total mass of the material, namely cherry coffee (kg), T_r is the temperature of the drying room (^oC), Ta is the ambient temperature (^oC), and C_{pb} is the specific heat of the material, namely cherry coffee (kJ/kg^oC) based on equation (4) (Casanova et al., 2013).

$$C_{pb} = 1{,}4392\ K_a + 1{,}2643 \tag{4}$$

Q_2 is the heat used to heat the water in the material, as in equation (5). m_a is the mass of water, and C_{pa} is the specific heat of water (kJ/kg^oC).

$$Q_2 = m_a C_{pa}(T_r - T_a) \tag{5}$$

Q_3 is obtained based on the mass of water and the latent heat of vaporization of water as in equation (6), where hfg is the latent heat of vaporization of water (kJ/kg), m_{ah} is the mass of water evaporated (kg), m_i is the initial mass of the material (kg), and m_f is the final mass of the material (kg).

$$Q_3 = m_{ah} h_{fg} \tag{6}$$

$$m_{ah} = m_i - m_f \tag{7}$$

3. RESULTS AND DISCUSSION

The initial moisture content of cherry coffee used as a sample in the testing of the rotary dryer using LPG energy in this study was 62.84%. Cherry coffee was dried until it reached a maximum moisture content of 12.25% based on the guidelines of the National Standardization Agency of the Republic of Indonesia. The general quality requirement for maximum coffee moisture content is 12.5% (SNI, 2008). In the study, it was found that the use of a rotary dryer with LPG energy was able to reduce the moisture content of cherry coffee by 9.95% in 20 hours.

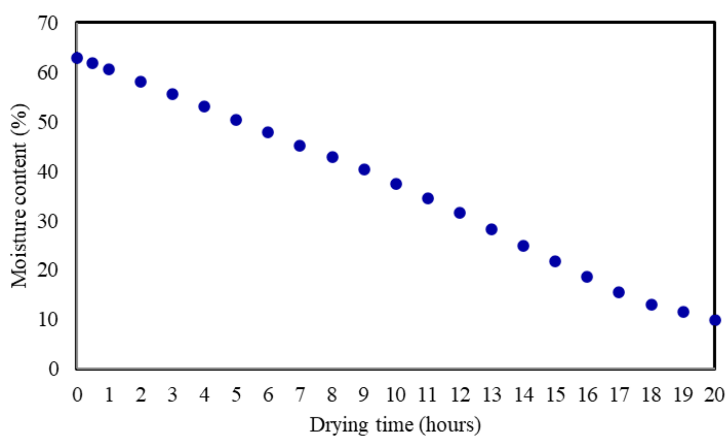

Figure 3. Coffee cherry moisture content for a drying time of 20 hours

The time required to dry cherry coffee is shorter compared to sun drying, as produced in the research of Susana et al. (2023), which took 16 days to produce a moisture content of 13.14%. Figure 3 shows the drying process with an LPG rotary dryer to produce a moisture content of cherry coffee for 20 hours. From Figure 3, it can be explained that the initial moisture content of cherry coffee of 62.84% can be reduced within 18-19 hours to reach moisture content according to the SNI standard of 12.5%. In the study, it was found that within 18-19 hours, it was able to reach a moisture content of 13.09-11.47%. The temperature for the drying process with LPG energy tends to be constant. Lower temperatures were found at the beginning until 4 hours, as shown in Figure 4. The ignition of the LPG stove influences this at hour 0, which is just starting, so that heat transfer from LPG to the drying room has not occurred and still follows the ambient temperature. Next, until the 4th hour, heat transfer occurs from LPG to the drying room in the heating condition of the material and the drying room. In addition,

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the moisture content of the cherry coffee is still high, so the heat transfer process is relatively slow due to the greater heat used to evaporate the water in the cherry coffee.

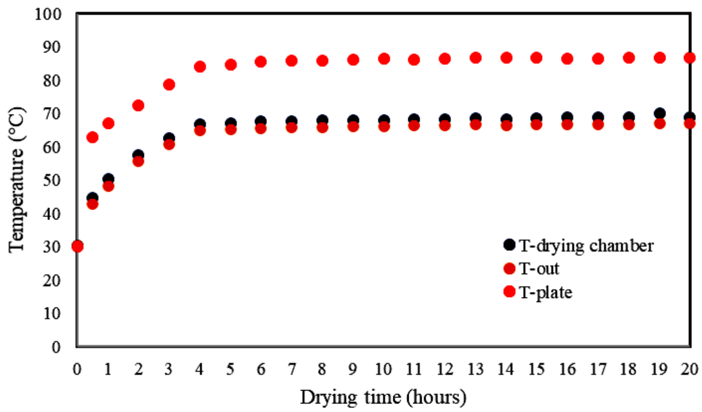

Figure 4. Temperature distribution of LPG energy rotary dryer

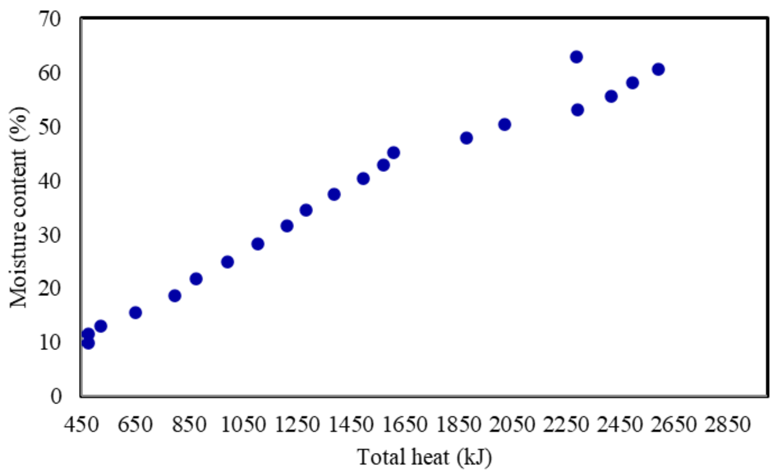

Figure 5. Distribution of total heat used on the moisture content of cherry coffee

The use of LPG as an energy source in the drying process provides a temperature in the drying chamber that tends to be stable from the 4th hour to the 20th hour. The average temperature of the drying chamber is 63.92°C with a range of 30.2-70°C. This temperature is produced through the heat transfer process from the LPG stove flame that burns the bottom plate of the drying chamber. The heat from the plate temperature is transferred into the drying chamber. The average plate temperature is 80.73°C with a range of 30-86.8°C. The study also found that the outlet temperature of the drying chamber was relatively high, namely an average of 62.07°C with a range of 30.2-67°C. Based on these conditions, it is possible to increase the load of dried cherry coffee, which is more than 10 kilograms, which in this study used a load of 10 kilograms of cherry coffee. Compared to drying cherry coffee with a load of 10 kilograms using solar drying in the study of Susana et al. (2023), which used an ambient temperature of 29.51°C, it took longer. The higher temperature of a rotary dryer compared to the sun affects a shorter drying time. Increasing temperature causes a decrease in drying time (Waheed and Komolafe, 2019; Dasore et al., 2020). The drying process with an LPG-fueled rotary dryer can be said to be much more optimal than drying in the sun, which relies on ambient temperature. Based on testing of the LPG-powered rotary dryer, it was found that the drying temperature is suitable for drying cherry coffee. The drying temperature is uniform, and the cherry coffee dries evenly. In addition, the drying time is shorter than drying in the sun. The drying temperature significantly affects changes in the moisture content of the material. The moisture content of the material has an impact on the total heat used in the drying process. Figure 5 presents the total heat used in the

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drying process for 20 hours of testing. This total heat is based on the sensible heat of the material, the heat to evaporate the water of the material, as well as the mass of water and the latent heat of evaporation of water.

Based on Figure 5, the total heat used in drying cherry coffee shows that the lower the moisture content, the lower the total heat used. This occurs from 1 hour of the drying process to the end, namely the 20th hour. An exception occurs when, at the beginning of the drying process, namely from 0 to 0.5 hours, the total heat used does not follow the trend of decreasing moisture content. This phenomenon occurs because the temperature has not changed, and the heat transfer from the energy source is not evenly distributed in the drying room and cherry coffee. A comparison of temperature with total heat used during the cherry coffee drying process is shown in Figure 6.

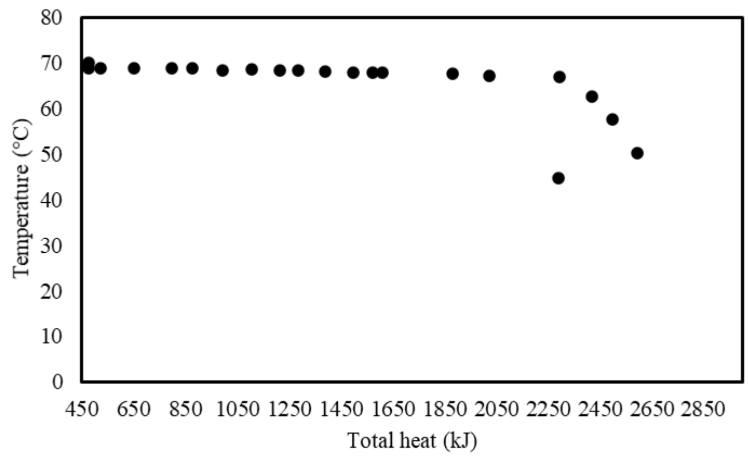

Figure 6. Distribution of total heat used against drying temperature

Figure 6 shows that the total heat used in the drying process deviates at 0-0.5 hours. At 0 hours and 0.5 hours, it is the beginning of the drying process, as presented in Figure 7.

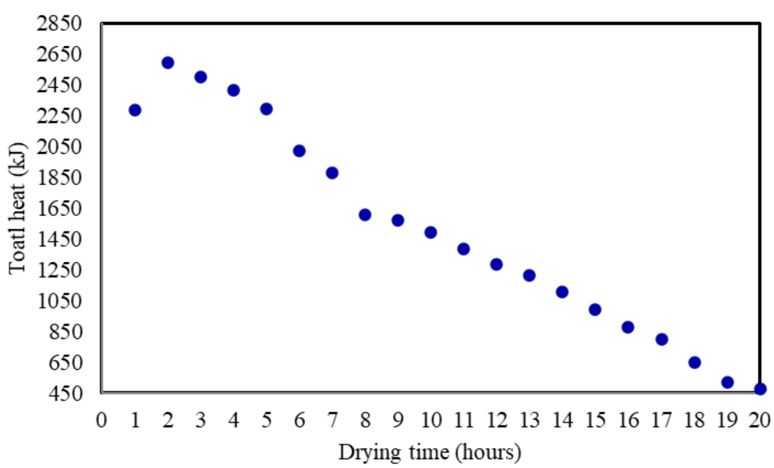

Figure 7. Distribution of total heat used during the 20-hour drying process

The temperature and total heat used at 0 and 0.5 hours were 30.2^{o}C and 44.6^{o}C, and 1370.13 kJ and 1612.23 kJ, respectively. Conditions like this can be ignored. This is in accordance with Hariyadi (2018), who states that during the drying experiment, the initial drying stage is a phase of increasing speed that is relatively short, so it can be ignored when calculating the drying time. Based on the drying curve from Berk (2009) that drying consists of three stages, namely stage I as a phase of increasing speed, stage II as speed, and stage III as the drying speed increases as the water in the material decreases. The total heat used during the drying process tends to decrease following the decrease in the moisture content of cherry coffee. The average total heat used in the coffee cherry drying process for 20 hours was 1460.62 kJ with a range of 476.4-2117.53 kJ. This condition causes the temperature outside the drying room to be relatively high, as shown in Figure 4, due to the influence of high moisture content and during drying, evaporation of the moisture content of the material occurs, which impacts the energy absorption process by the coffee cherry from the dryer. Rotary dryers with LPG energy sources do not depend on environmental temperature, so the time required in the drying process is shorter than solar drying. The use of LPG as an energy source for rotary dryers is very affordable because they still receive subsidies from the state. This applies to small farmers in Indonesia with the highest retail price of IDR 19,000/kg. LPG used as an energy source for rotary dryers is very beneficial for small farmers as it provides a sustainable drying process.

4. CONCLUSION

The results of testing the rotary dryer using a liquefied petroleum gas (LPG) energy source in drying cherry coffee obtained findings. The initial moisture content of cherry coffee of 62.84% can be reduced to 9.95% in 20 hours. This moisture content meets the quality requirements of the Indonesian National Standard with a maximum provision of 12.5%. The dryer is able to produce an average drying temperature of 63.92^{o}C with a range of 30.2-70^{o}C. The outlet temperature of the drying chamber is still relatively high, with an average of 62.07^{o}C and a range of 30.2-67^{o}C. Based on this condition, it is possible to increase the load of dried cherry coffee, which is more than 10 kilograms, which in this study used a load of 10 kilograms of cherry coffee. The total heat used during the drying process is an average of 1460.62 kJ with a range of 476.4-2117.53 kJ. It was found that the phenomenon at the beginning of drying from 0-0.5 hours occurred in a low-temperature condition, with the total heat used deviating from the existing distribution pattern. This happens as an impact of the increasing speed phase, and this condition can be ignored so that the drying process can be evaluated from 1 hour to 20 hours. With the government subsidy for LPG for small farmers, this rotary dryer is an appropriate tool in the drying process on a small farmer scale. Drying can be done continuously because it does not depend on the weather.

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NOMENCLATURE

C_{pb} : Specific heat of material (kJ/kg^{o}C)
h_{fg} : Latent heat of vaporization of water (kJ/kg)
K_a : Moisture content (%)
m_t : Mass total of coffee cherry (kg)
m_k : Mass dry of coffee cherry (kg)
Q : The amount of heat used for drying (kJ)
Q_1 : Sensible heat of material (kJ)
Q_2 : Heat to evaporate the water material (kJ)

REFERENCES

Alit, I.B., Susana, I.G.B., Kinerja pengering satu tungku penukar panas dengan energi sekam padi untuk mengeringkan pisang menggantikan pengeringan langsung matahari, Dinamika Teknik Mesin, 14(1), 45-53, 2024.

Berk, Z., Food process engineering and technology, 2th, Academic Press Publishers, Cambridge, United States, 2009.

Boonloi, A., Jedsadaratanachai, W., Thermal performance assessment in a circular tube fitted with various sizes of modified v-baffle: a numerical investigation, Frontiers in Heat and Mass Transfer (FHMT), 16, 17, 2021.

Brooker, D.B., Bakker-Arkema, F.W., Hall, C.W., Drying and storage of grain and oilseeds, 4th, Van Nostrand Publishers, 1992.

Casanova, P., Corrêa, P.C., Solís, K., Campos, J.C.C., Thermal properties of Conilon coffee fruits, IOSR Journal of Engineering, 3(11), 29-35, 2013.

Çengel, Y.A., Boles, M.A., Kanoglu, M., Thermodynamics an engineering approach, 9th, McGraw-Hill Publishers, 2019.

Çengel, Y.A., Cimbala, J.M., Ghajar, A.J., Fundamental of Thermal-fluid Sciences, 6th, McGraw Hill eBook Publishers, 2022.

Burgess-Limerick, R., Participatory ergonomics: Evidence and implementation lessons, Applied Ergonomics, 68, 289-293, 2018.

Dasore, A., Polavarapu, T., Konijeti, R., Puppala, N., Convective hot air drying kinetics of red beetroot in thin layers, Frontiers in Heat and Mass Transfer, 14(23), 1-8, 2020.

Ettahi, K., Chaanaoui, M., Sébastien, V., Abderafi, S., Bounahmidi, T., Modeling and design of a solar rotary dryer bench test for phosphate sludge, Hindawi Modelling and Simulation in Engineering, 5574242, 2022.

Giudice, A.D., Acampora, A., Santangelo, E., Pari, L., Bergonzoli, S., Guerriero, E., Petracchini, F., Torre, M., Paolini, V., Gallucci, F., Wood chip drying through the using of a mobile rotary dryer, Energies, 12(9), 1590, 2019.

Hamdani, Rizal, T.A., Muhammad, Z., Fabrication and testing of hybrid solar-biomass dryer for drying fish, Case Studies in Thermal Engineering, 12, 489-496, 2018.

Hariyadi, T., Pengaruh suhu operasi terhadap penentuan karakteristik pengeringan busa sari buah tomat menggunakan tray dryer, Jurnal Rekayasa Proses, 12(2), 104-113, 2018.

Kabeel, A.E., Abdelgaied, M., Performance of novel solar dryer, Process Safety and Environmental Protection, 102, 183-189, 2016.

Li, T., Li, C., Li, B., Li, C., Fang, Z., Zeng, Z., Characteristic analysis of heat loss in multistage counter-flow paddy drying process, Energy Reports, 6, 2153-2166, 2020.

Li, Z., Zhang, Z., Feng, Z., Chen, J., Zhao, L., Gao, Y., Sun, S., Zhao, X., Song, C., Energy transfer analysis of the SH626 sheet rotary dryer on the production system perspective, Energy Reports, 8, 13-20, 2022.

Menteri Pertanian Republik Indonesia, Pedoman penanganan pascapanen kopi, Lampiran Peraturan Nomor 52/Permentan/OT.140/9/2012, 909, 6-27, 2012.

Nazghelichi, T., Kianmehr, M.H., Aghbashlo, M., Thermodynamic analysis of fluidized bed drying of carrot cubes, Energy, 35(12), 4679-4684, 2010.

Nguimdo, L.A., Noumegnie, V.A.K., Design and implementation of an automatic indirect hybrid solar dryer for households and small industries, International Journal of Renewable Energy Research, 10(3), 1415-1425, 2020.

Oshwiki, Heat at work-guidance for workplaces, European Agency for Safety and Health at Work, 2023, Available online: https://oshwiki.osha.europa.eu/en/themes/heat-work-guidance-workplaces (accessed on August 28, 2024).

Oyewola, O.M., Petinrin, M.O., Sanusi, H.O., Flow and heat transfer characteristics in channels with piriform dimples and protrusions, Frontiers in Heat and Mass Transfer, 20, 16, 2023.

Paristiawan, P.A., Ghazali, I., Aryanti, D., Budiarjono, Amanah, A., Idris, M., Hermansyah, D., Ali, E.A.B., A review of solar drying design and architecture: direct, indirect and mixed-mode solar dryer, Jurnal Polimesin, 2(20), 200-205, 2022.

SNI (Standar Nasional Indonesia), Biji kopi, Badan Standardisasi Nasional, SNI 01-2907-2008, 2008.

Sormunen, E., Mäenpää-Moilanen, E., Ylisassi, H., Turunen, J., Remes, J., Karppinen, J., Martimo, K.P., Participatory ergonomics intervention to prevent work disability among workers with low back pain: a randomized clinical trial in workplace setting, Journal of Occupational Rehabilitation, 32, 731-742, 2022.

Susana, I.G.B., Alit, I.B., Okariawan, I.D.K., Rice husk energy rotary dryer experiment for improved solar drying thermal performance on cherry coffee, Case Studies in Thermal Engineering, 41, 102616, 2023.

Susana, I G.B., Improve of worker performance and quality of anchovy with ergonomic hybrid solar dryer, Journal of Engineering and Applied Sciences, 13(5), 1662-1667, 2018.

Trojosky, M., Rotary drums for efficient drying and cooling, Drying Technology, 37(5), 632-651, 2019.

Waheed, M.A., Komolafe, C.A., Temperatures dependent drying kinetics of cocoa beans varieties in air-ventilated oven, Frontiers in Heat and Mass Transfer, 12(8), 1-7, 2019.

Xie, Q., Chen, Z., Mao, Y., Chen, G., Shen, W., Case studies of heat conduction in rotary drums with L-shaped lifters via DEM, Case Studies in Thermal Engineering, 11, 145-152, 2018.

https://doi.org/10.29303/dtm.v15i1.968