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Psychrometric Performance of the Air Dehumidifier Base Clothes Dryer

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Abstract

Drying clothes with dehumidifier machine and additional IR light experiments were conducted to show the psychrometric performance of dehumidification drying. Experiment of dehumidification drying 7.07 kg wet clothes to 4,78 kg dry clothes and 9.9 kg wet clothes to 7.67 kg dry clothes were applied. Variation of 715 W dehumidifier and 375 W IR were conducted. Measurement of room and environment temperatures and humidity were performed. The results show that additional IR make the drying process faster. However, it reduces drying effectivity. The efficiencies of drying are 109%, 96%, 100%, and 79% for drying 4.78 kg dry clothes with dehumidifier, drying 4.78 kg dry clothes with dehumidifier + IR, drying 7.67 kg dry clothes with dehumidifier, and drying 7.67 kg dry clothes with dehumidifier + IR. The numbers also reveal need of adopting drying COP using closed loop heat pump dehumidification to be ratio of heating and cooling energy over the supplied energy plus one.

Keywords: Clothes Dryer 1, COP 2, Dehumidifier 3

1 Introduction

Drying is a process of removing water content from solid material with heat and mass transfer process technique. It is applied in many activities, from body drying to food processing in industries. People need drying in food processing for preserving vegetable, fruits, fish and meat, grain, herbs, and spices [1], [2], [3], [4]. In production and maintenance of furniture, kitchen equipment, drying is important factor [5]. The activity is also a process that people conduct for preparing building materials such as timber and bricks [6]. In clothing, drying is applied for production and maintenance processes [7]. In clothes production, the drying process is applied for raw material processing, dying, and maintenance of the products.

Many drying processes are based on heating the product and lowering the humidity of the circumstance. Solar drying is very popular due to its cost and simplicity. People do not need to pay fuel for it and it can be done without any special equipment to allow the process happens. Kiln is applicable for many drying processes and has wide range of temperature [8], [9], [10]. A kiln can be applied for food processing with temperature controlled to be less than 50oC to raw material drying such as cement production with temperature of 800oC. The other common drying methods are hot air drying [11], ultra-sound dryer [12], [13], refrigerated and freeze drying [14], [15], dehumidification drying [16] and any other methods. Generally, most of the drying process consists of application of low humidity air which has less moisture pressure than the water pressure of the material surface. This basic principle allows the water vaporized easily.

Dehumidification is a potential method for clothes drying due to its low energy cost. Purwadianta and Sugiharto [7] reported performance of the dehumidification drying for clothes with variation of clothes number and type of flowing air. With 200 W R134a heat pump of 7.94 COP for drying room of 1.39 m3, 15 – 45 cotton clothes of 2.55 – 6.51 kg need drying time of 210 – 450 minutes. However, a deeper analysis concerning about the drying effectivity and psychrometric of the drying performance was still out of the discussion. The gap will be the main topic of this work. The report will also include effect of IR additional heat comparing to the absence of the equipment for clothes drying.

To show the psychrometric drying performance, the rest of the article is composed of methodology presenting theory of dehumidifying drying, analysis of the psychrometric, vapor compression heat pump, experiment setup, and the proposed performance analysis. The third section is about the data of the experiment and its discussion. Final part of the presentation is the conclusion.

2 Material and Methods

The drying effectivity consists of parameters regarding the process. It considers time for drying, used energy for drying, human resource necessity, and product quality. Those parameters co-exist and are intertwined. In small scale clothes drying, the aspects of human necessity, product quality, and time can be neglected. Household drying can be done by a single worker with equal product quality. Therefore, energy analysis becomes the focus of the discussion with energy effectivity for drying as the main parameter.

The method of the work consists principle of dehumidifying drying theory, psychrometer analysis, experiment setup, and parameters of the drying effectivity. The dehumidifying theory shows the theory of convective drying applied in clothes. The psychrometer analysis focuses on theory of the humidity relation to the air condition. The experiment setup mentions about the equipment where the experiment was conducted and it's the variation of the conditions. The parameter explains relation of energy and drying load.

A. Dehumidification drying

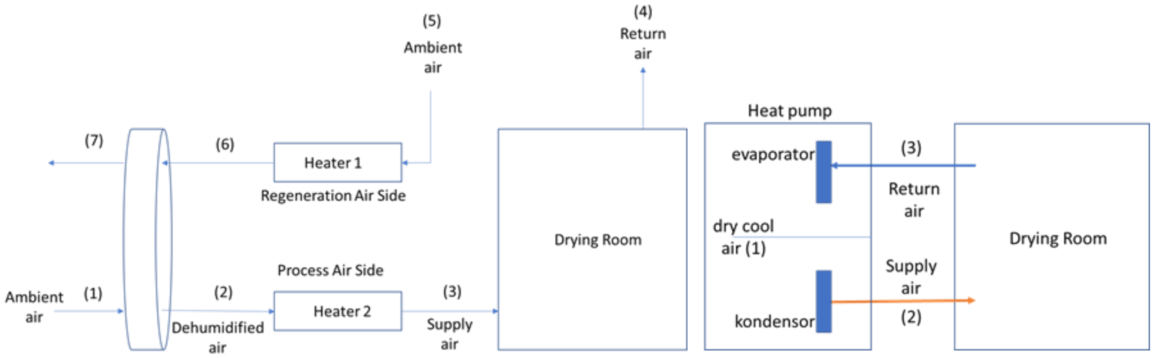
Dehumidifying drying is a method for removing water from the solid called moisture content using reduction of the vapor pressure reduction. This vapor pressure decrease can be made using some methods. To reduce the vapor pressure, desiccant and heat pump approaches can be applied. Desiccant can be used to be adsorbent, and the moist becomes the adsorbate. While the moist of the air is adsorbed into the desiccant, the vapor pressure of air decreases. This decrease allows the moist on the surface of the adsorbate releases the moist content easily. The desiccant method has drawback of releasing the water content from the adsorbent which need special treatment. The heat pump uses the psychrometric principle for reducing the moisture pressure of the air. To reduce the vapor pressure, the evaporator of the heat pump reduces the air temperature beyond its saturated temperature. The condensed water is collected and the air is recirculated. The drawback of the method is energy need during the cycle. The cycle of condensation means latent energy of the water released.

The dehumidifying drying principle is shown in Figure 1. The Fig. 1 (a) and Fig. 1(b) are the desiccant dehumidifier drying and the heat pump dehumidifier drying, respectively. Fig. 1 (a) shows that ambient air is transformed into hot dry air as the air supply for drying room. The desiccant is used to adsorb the moist of the air. The heater is applied for increasing the temperature. The Fig. 1 (b) mentions that air is circulated through heat pump element and drying room. The air from drying room (return air) is dehumidified using evaporator to be dry cool air. Then its temperature is increased through condenser and supplied to drying room as hot dry air.

B. Psychrometric process of closed loop heat pump dehumidification drying

The drying process of dehumidification drying consists of supplying hot dry air, removing water from the load, and removing water from the air. In closed loop heat pump dehumidifying drying process, the evaporator is applied to reduce the moist of the air. It provides dry cool air as consequences of the condensation process in evaporator. Then the condenser increases its temperature to provide hot dry air as the supply air for drying room. In drying room, the hot dry air absorbs the moist from the object. General psychrometric process of closed loop dehumidifying drying process is shown in Fig. 2.

The Fig. 2 shows that cool dry air, hot dry air, and the return air are numbered (1), (2), and (3) respectively. The process of (1) to (2) happens by condenser.



(a) (b)

Figure 1. (a) Schematic desiccant dehumidifying drying process.[17], [18]; (b) Schematic closed loop heat pump dehumidifying drying process.

The process of (2) to (3) takes place in drying room as the drying process. Accordingly, the process of (3) to (1) is located at the evaporator. At this point, temperature is decreased to (3a) where some of the moist the condensed through decreasing temperature to be point (1). The condensed moist is equal to enthalpy difference of the point (3a) and (1).

C. The experiment setup.

To earn the psychrometric performance of the humidifying drying for clothes, the equipment is setup as shown in Fig. 3. A built-up dehumidifier with capacity of 30 l/day is applied instead of customized vapor compression machine. The machine uses R290 refrigerant with operating pressure of 2.6 MPa and 1.0 MPa for the high and low pressures, respectively. The compressor rate is 715 W with the current of 3.2 A. The inlet of the wet air flow is on the back part of the apparatus.

The experiment was conducted for 25 and 35 cotton clothes. The dry weight of the clothes were 4.78 kg and 6.76 kg, for 25 and 35 clothes, respectively. Meanwhile, the weight of 25 clothes was 7.07 and the weight of 35 wet clothes was 9.90. The wet clothes were put into the drying room and the machine was started.

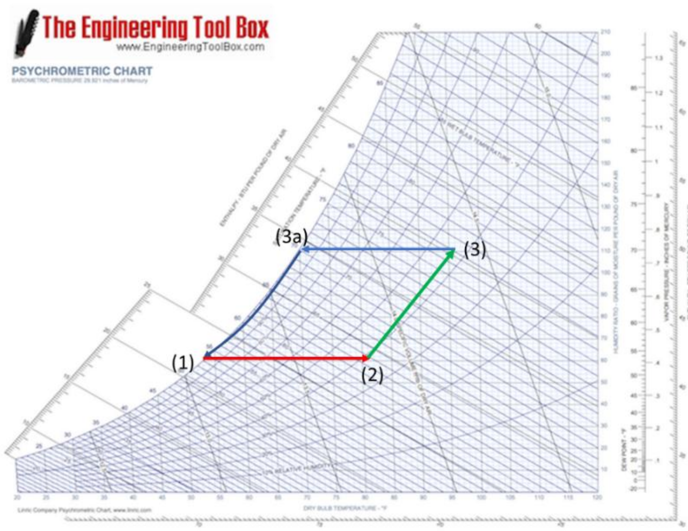


Figure 2. The psychrometric process of closed loop heat pump dehumidifying drying regarding the air as shown in Figure 1(b).

Every 30 minutes, the measured weight of the clothes was recorded in addition to wet bulb and dry bulb temperatures of drying room and the environment. The condensed water was collected and its volume was measured at the same time. The temperature of inlet air and the outlet air were also recorded. The experiments were stopped after the targeted dry clothes weight reached.

In addition to the dehumidification drying process, IR light was applied for every condition to inject additional heat to the room. The IR light was provided by an IR lamp located above the clothes. The light had rate of 375 W. Therefore, variation of the experiment can be seen in Table 1.

D. Performance Measurement

The drying performance was measured as ratio of drying capacity and energy rate injected to the drying system. The drying efficiency is defined as ratio of energy for evaporating the water from the clothes to energy supplied for the system. The total energy for evaporating is calculated from the water latent proportional to amount of energy as

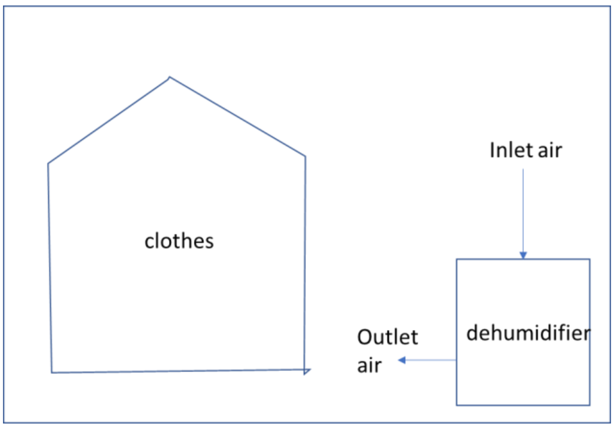


Figure 3. The apparatus setup of the experiment.

Table 1. Experiment condition setup

Load Variation	Dryer Variation
25 clothes, 4.78 kg dry	715 W dehumidifier
35 clothes, 6.76 kg dry	715 W dehumidifier
25 clothes, 4.78 kg dry	715 W dehumidifier + 375 W IR
35 clothes, 6.76 kg dry	715 W dehumidifier + 375 W IR

shown in equation (1), with E, m_v, and L_v as the energy of vaporization, vapor mass, and vaporization latent, respectively. The vapor mass is assumed as amount of water loss from the clothes.

$$E_v = m_v * L_v \tag{1}$$

Then, the efficiency of drying is calculated using equation (2), with E_s as the energy supplied to the system for operation.

$$\eta = \frac{E_v}{E_s} * 100\% \tag{2}$$

The energy supplied to the system for operation is calculated according to equation (3), with P_d, and P_{iR} are the power of dehumidifier, and IR lamp, respectively.

$$E_s = \sum_{i=1}^{n} \left(P_d + P_{iR}\right) \Delta t \tag{3}$$

The Δt is time scale measurement (30 minutes) and n as the amount of measuring time until the dry weight clothes reached.

3 Results and Discussions

The temperatures of the dehumidifier rooms, temperature of the environment, and the condensed water collected in every 30 minutes for 4.78 kg, and 6.76kg clothes are presented in Table 2, and Table 3 below, respectively. The tables reveal that more clothes need more time to finish for drying. It is confirmed that more clothes related to more water to dry up. The dry bulb drying room temperatures tend to increase as time going up. It also takes place for the wet bulb. The environment temperature affects the drying room temperature. If the environment temperature increase, the drying room temperature will increase as well. It shows that heat release from drying room to the environment affects the drying temperature.

The accumulative water condensed during drying process for 4.78 kg, and 6.76 kg clothes are shown in Fig. 4. The table mentions that condensed water capacity decreases as time going up. The water content of the clothes was 2.29 and 3.29 litres for 4.78 and 3.14 for 4,78 kg and 6.76 clothes. Among the evaporated water, 1.96 and 2.62 litres were condensed. It was 85% and 83% of the water evaporated in drying process. Results and discussions are written with times new roman 12 pt, 1 (one) column, 1.5 space density one space density, on A4 paper with a top-left margin of 3 cm and bottom-right 3.5 cm.

Table 2. Drying condition of 4.78 kg clothes

Time (min)	Drying Room Temperature (C)		Environment Temperature (C)		Water Condensed (kg)
	Tdb	Twb	Tdb	Twb	
0	36.4	29.9	26.5	25.5	0.000
30	42.4	34.9	27.0	25.0	0.545
60	45.4	36.4	27.5	25.0	0.545
90	45.4	36.4	27.5	24.5	0.405
120	47.4	34.9	27.5	24.5	0.330

Table 3. Drying condition of 6.76 kg clothes

Time (min)	Drying Room Temperature (C)		Environment Temperature (C)		Water Condensed (kg)
	Tdb	Twb	Tdb	Twb	
0	33.0	40.5	27.0	24.0	0,000
30	39.0	46.0	27.0	24.0	0,555
60	39.5	47.0	28.0	24.0	0,535
90	42.0	51.0	28.0	24.0	0,540
120	46.5	59.0	27.5	24.5	0,470
150	43.0	55.0	25.0	25.0	0,335
180	45.5	55.5	25.5	25.0	0,185

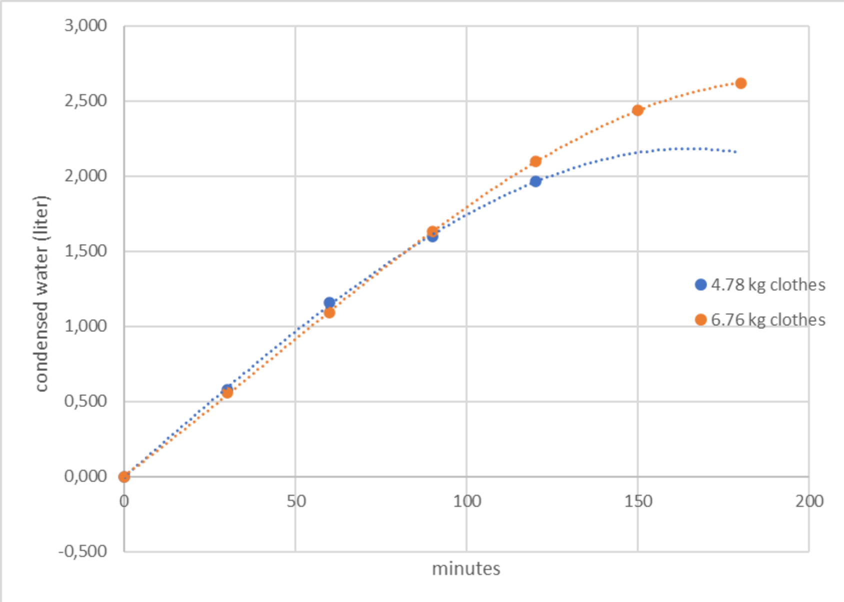


Figure 4. Water condensed during the drying process.

Additional IR Light of 375 W reduced time of drying by 30 minutes. The drying time of 4.78 kg clothes became 120 minutes using additional 375 W IR light. Without IR light, the drying time was 150 minutes. The similar pattern happens to 6.76 kg clothes. Time for drying with 375 W IR light got less to be 150 minutes from 180 minutes without IR. The cumulative condensed water according time for drying using 715 W dehumidifier with additional 375 IR Light is shown in Fig. 5.

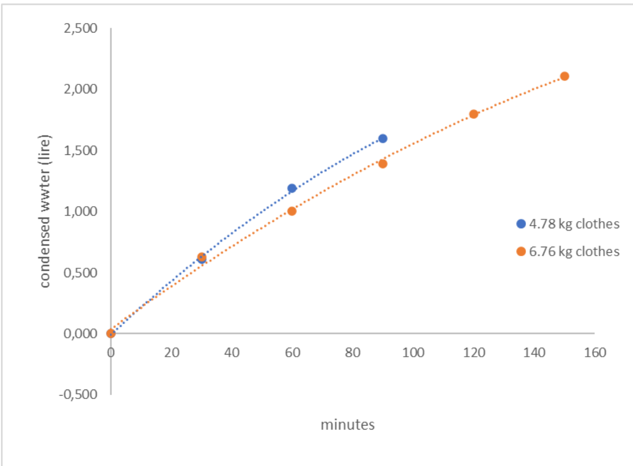


Figure 5. The condensed water accumulation during drying using dehumidifier and additional 375 W IR light.

Considering energy of drying as the main parameter for performance, it can be said that drying using 715 W dehumidifier without additional 375 W IR light is more efficient than drying the same clothes using dehumidifier with additional 375 W IR light. The comparison of the energy efficiency as proposed in equation (2) is shown in Table 4. The 100% or more mentioned that there is regenerative process which mentions that the condensation taking place at the evaporator increase effectivity of drying process. In term of effectivity, the drying energy as evaporative energy needed for 4.78 kg clothes are 2248 kJ/kg and 2570 kJ/kg water for 715 W dehumidifier and 715 W dehumidifier + 375 W IR light, respectively. Accordingly, the 6.76 kg clothes need 2455 kJ/kg and 3119 kJ/kg drying energy for 715 W dehumidifier and 715 W dehumidifier + 375 W IR light drying respectively. It shows that 715 W dehumidifier with additional 375 W IR light needs more energy to evaporate every kg water from the wet clothes than 715 W dehumidifier only.

Table 4. Drying condition and energy efficiency

Drying equipment	4.78 kg clothes	6.76 clothes
715 W dehumidifier	109%	100%
715 W dehumidifier + 375 W IR light	96%	79%

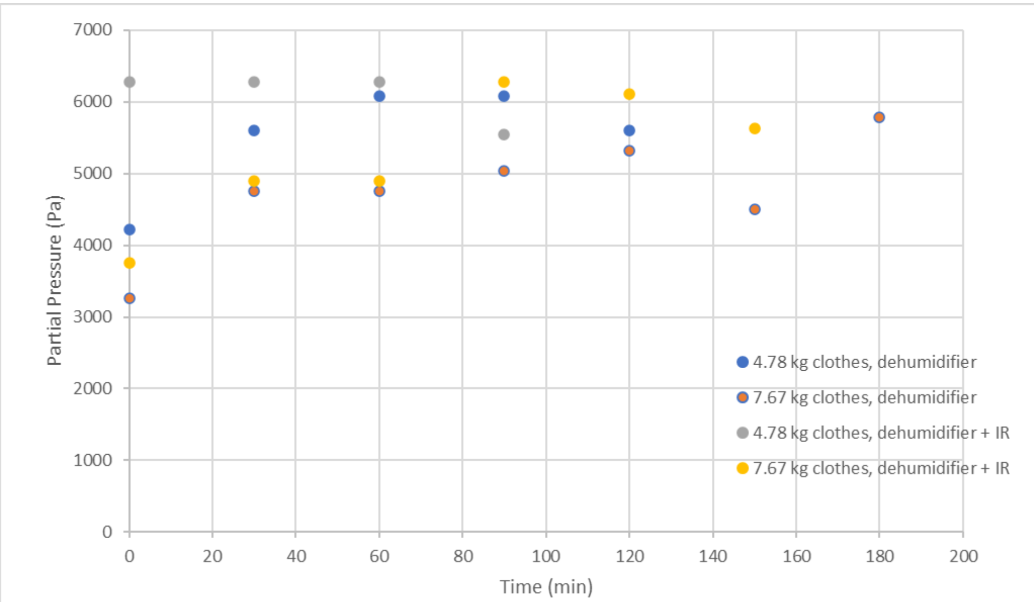


Figure 6. Partial Pressure of the moist in the drying room.

Fig. 6 explains the reason of energy effectivity of the equipment. The drying system with additional IR makes more moist content in the air of the drying room. In average, partial pressures of the moist in drying process of 4.78 kg are 5515 Pa and 6096 Pa of respective dehumidifier and dehumidifier + IR. Accordingly, the 7.67 kg clothes have 4775 Pa and 5262 Pa partial moist pressure in drying room with dehumidifier and dehumidifier + IR, respectively. Even the 7.67 kg clothes have less partial moist pressure, they attribute higher relative humidity than clothes of 4.78 kg. The partial humidity in average for the systems are 60.2%, 58.4%, 56.8%, and 48.9% in drying 4.78 kg clothes with dehumidifier only, 7.67 kg clothes with dehumidifier only, 4.78 kg clothes with dehumidifier + IR, and 7.67 kg clothes with dehumidifier + IR, respectively. It exposes the reason dehumidifier + IR needs less time than dehumidifier only even the absolute partial pressure is higher than drying with the dehumidifier only.

Air dehumidifier is a common machine for controlling air humidity in a room. It is a kind of heat pump using vapor compression machine working with the inlet air flowing through the evaporator for reducing air humidity and followed by heating up using condenser. The method implying COP of the drying approach as ratio of the combination of evaporator and condenser heat rate over the compressor inlet power. Higher COP means higher effectivity of energy usage during cooling process of air. At the same time, the cooling process implying reducing temperature of the wet air and condensation to the psychrometric system. Accordingly, the condenser releases heat to the air circulated in the drying room. It implies that both cooling process and heating process contribute into drying process. The cooling with absolute moist content reduction, while the heating reduces relative humidity of the circulated air. It is in accordance with the work of Purwadi and Prasetyadi [5].

4 Conclusions

The research mentions that dehumidification work well in drying the clothes with various weight. Generally, the drying time depends on weight of clothes. The efficiency of the energy for drying as ratio of the evaporative drying over supplied energy mentions a tricky condition as more clothes related to less partial pressure but the relative humidity implying drying time. The efficiencies of drying 4.78 kg clothes with dehumidifier, 4.78 kg clothes with dehumidifier + IR, 7.67 kg clothes with dehumidifier, and 7.67 kg clothes with dehumidifier + IR are 109%, 96%, 100%, and 79%, respectively. The efficiency which is higher than 100% revealed the condensation role for reducing the absolute humidity in dehumidification drying process using heat pump. The results suggest accommodation of heat pump drying process as ratio of cooling and heating energy over the supplied energy plus one.

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References

[1] S. Salve, A. M. Fulambarkar, and M. Arici, “Experimental studies on drying characteristics of green chilies in a solar dryer,” J Ther Eng, vol. 8, no. 5, pp. 1–8, 2022, doi: 10.14744/jten.2022.0000.

[2] G. Dadaev, S. Sultanova, J. Safarov, and Q. Mukhiddinov, “Calculation of the drying process of dietary materials in solar dryers,” in E3S Web of Conferences, EDP Sciences, Oct. 2023. doi: 10.1051/e3sconf/202343401035.

[3] N. Ahmed, J. Singh, H. Chauhan, P. Gupta, A. Anjum, and H. Kour, “Different Drying Methods: Their Applications and Recent Advances International Journal of Food Nutrition and Safety, 2013, 4(1): 34-42 International Journal of Food Nutrition and Safety Different Drying Methods: Their Applications and Recent Advances,” 2013. [Online]. Available: https://www.researchgate.net/publication/275650176

[4] Y. Çelik and B. B. Kenanoğlu, “The Effect of Different Drying Processes on the Quality of Pepper Seeds Harvested in Uşak Conditions,” 2022, [Online]. Available: https://creativecommons.org/licenses/bync/4.0/Availableonlinehttps://dergipark.org.tr/ijafls

[5] P. Kanisius Purwadi and A. Prasetyadi, “Characteristics of Wooden Furniture Drying Machine,” International Journal of Applied Sciences and Smart Technologies, vol. 4, no. 1, pp. 75–88, 2022.

[6] P. Kanisius Purwadi and A. Prasetyadi, “Air Circulation Types on Albizia Chinensis Refrigerated Drying.”

[7] D. Purwadianto and B. Sugiharto, “Performance of Low Power Electric Energy Clothes Dryers for Households,” International Journal of Applied Sciences and Smart Technologies, vol. 5, no. 1, pp. 39–54.

[8] A. S. Mujumdar, “Handbook of Industrial Drying.”

[9] S. K. Amponsah, H. Asare, H. Okyere, J. O. Owusu-Asante, E. Minkah, and H. K. Ketemepi, “Performance Characterization of a Locally Developed Fish Smoke-Drying Kiln for Charcoal and Briquette,” Journal of Agricultural Science, vol. 14, no. 11, p. 43, Oct. 2022, doi: 10.5539/jas.v14n11p43.

[10] H. S. Lee et al., “Design of a modified charcoal production kiln for thermal therapy and evaluation of the charcoal characteristics from this kiln,” Bioresources, vol. 14, no. 3, pp. 7275–7284, Aug. 2019, doi: 10.15376/biores.14.3.7275-7284.

[11] X. Song et al., “Effect of Hot-Air Drying Conditions on the Drying Efficiency and Performance of a Waterborne Coating on Pine Wood,” Forests, vol. 14, no. 9, Sep. 2023, doi: 10.3390/f14091752.

[12] S. Tüfekçi and S. G. Özkal, “Application of Ultrasound in Food Drying,” Pamukkale University Journal of Engineering Sciences, vol. 21, no. 9, pp. 408–413, 2015, doi: 10.5505/pajes.2015.05902.

[13] F. Salehi, “Effects of ultrasonic pretreatment and drying approaches on the drying kinetics and rehydration of sprouted mung beans,” Legume Science, 2023, doi: 10.1002/leg3.211.

[14] A. M. N. Lal et al., “A comparison of the Refrigerated Adsorption Drying of Daucus carota with fluidized bed drying,” Lwt, vol. 154, p. 112749, 2022, doi: 10.1016/j.lwt.2021.112749.

[15] J. Garcia-Noguera, F. I. P. Oliveira, C. L. Weller, S. Rodrigues, and F. A. N. Fernandes, “Effect of ultrasonic and osmotic dehydration pre-treatments on the colour of freeze dried strawberries,” J Food Sci Technol, vol. 51, no. 9, pp. 2222–2227, 2014, doi: 10.1007/s13197-012-0724-x.

[16] A. Prasetyadi, R. Sambada, and P. K. Purwadi, “Development of a new fast drying determinant method using resistivity for the industry of coconut shell charcoal briquettes,” Eastern-European Journal of Enterprise Technologies, vol. 1, no. 8 (127), pp. 58–66, Feb. 2024, doi: 10.15587/1729-4061.2024.297541.

[17] S. Hanif, M. Sultan, T. Miyazaki, and S. Koyama, “Investigation of energy-efficient solid desiccant system for the drying of wheat grains,” International Journal of Agricultural and Biological Engineering, vol. 12, no. 1, pp. 221–228, 2019, doi: 10.25165/j.ijabe.20191201.3854.

[18] M. Sultan, S. Hanif, T. Miyazaki, S. Koyama, and B. Road, “Evaluation of Solid Desiccant based Drying System for Energy-Efficient Drying of Agricultural Products,” 2018, doi: 10.11322/tjsrae.18-40AC_OA.