

EFFECTIVENESS OF CASCARA SUN DRYING USING ALUMINIUM PAN

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Abstract. The cascara drying process is usually done by drying wet coffee peels for about 5 days with open sun drying. This study evaluated the effectiveness of drying wet coffee peels into cascara by open sun drying on an aluminium. Analysis was carried out to determine the moisture content, drying rate, and drying efficiency. The material used was Arabica cherry coffee peels, which were dried using aluminium pans on the, drying floor. The decrease in cascara mass was recorded every 60 minutes, while solar irradiation was recorded every 0.5 minutes. The results showed that drying cascara using solar energy on aluminium pans took a shorter time, took only two days, compared to using solar energy on perforated racks. The resulting cascara moisture content was approximately $10.02 \pm 0.25\%$. The initial drying rate is approximately 0.33 kg/h/m^2 and the final drying rate reaches $0.04 \pm 0.01 \text{ kg/h/m}^2$. It is known that the higher the sunlight irradiation, the higher the drying rate when the material's moisture content is still high. Cascara drying efficiency ranges from 67.26% at the beginning of the drying process to 3.6% towards the end of the drying process. The use of an aluminium pan increased the effectiveness of sun drying.

1 Introduction

Coffee plants are widely cultivated in Indonesia, with coffee bean production reaching 789,233 tons per year [1]. Indonesia ranks 4th in the world as a coffee producer [2]. Coffee beans are obtained from the peeling of harvested coffee cherries. Peeling can be done in wet or dry conditions. Coffee cherries peel have not been optimally utilized so they are often wasted or only used as animal feed. Coffee cherry peels are actually rich in bioactive components such as tannins, anthocyanins, and caffeine. One use of coffee cherries peel for food is to make cascara, which is similar to tea after the coffee cherries peel are dried [3, 4].

The process of drying coffee peels into cascara is usually carried out using conventional drying methods using solar energy. Drying is done by placing the coffee peels on perforated rack or woven bamboo and drying them directly under sunlight. This drying method is very cheap and easy, but it takes a long time [6]. Drying with this method takes about 5 days or more. Drying using perforated racks relies on natural air conditions from the environment which often mix with evaporated water vapor from the soil surface so that the drying process is slow.

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The process of drying coffee peels into cascara is faster and more affordable. One method that can be done is by drying the coffee peels using aluminium pans. Drying on an aluminum pan allows additional heat from the hot aluminum surface to the material being dried. The dried material will experience additional heat by conduction from the surface of the aluminum pan. Therefore, it is necessary to research the drying of coffee peels using solar energy on aluminium pans. This study aims to determine the drying rate, drying time, water content and drying efficiency.

2 Material and Methods

This research was conducted in July and August 2025 at the Renewable Energy Engineering Laboratory of the Jember State Polytechnic. The materials used in this study were Arabica coffee peels obtained from plantations around Jember. The research was conducted by drying the Arabica coffee peels using solar energy. Drying was carried out by placing the coffee peel samples on an aluminium pan and exposing them to direct sunlight, as with conventional drying methods. The aluminum pan used has a surface area of 0.072 m². The sample in each aluminum pan is 550 grams with a layer thickness of 1 cm. The drying rate is calculated by the formula:

$$R_d = \frac{\Delta m}{A \cdot t} \quad (1)$$

R_d is the drying rate (kg/h.m²), Δm is the reduction in sample mass (kg), A is the surface area (m²), and t is the drying time (h).

Coffee peel samples were weighed every hour to determine their mass decrease. Solar irradiance data was measured using a Lutron SPM-1116-SD solar power meter and recorded every 0.5 minutes. The moisture content of the coffee peel samples was determined using gravimetric and oven-dried methods. [7].

3 Results and Discussions

The research yielded data on the time required to dry coffee peels using solar energy on aluminium pans. Other data included moisture content reduction, which was needed for drying rate analysis. Furthermore, solar irradiance data was also obtained, which was needed for drying efficiency analysis.

3.1 Drying Time

The drying time of coffee peels using sunlight on aluminium trays is 2 days with good weather. The drying time is faster compared drying coffee peels directly on the ground using a mat (Figure 1) or on a perforated racks or woven bamboo, which can take 5 days or more. Drying process using sunlight on perforated rack or woven bamboo is greatly influenced by ambient air conditions (Figure 2). Air can freely flow and exchange around the product placed on the perforated rack or woven bamboo.

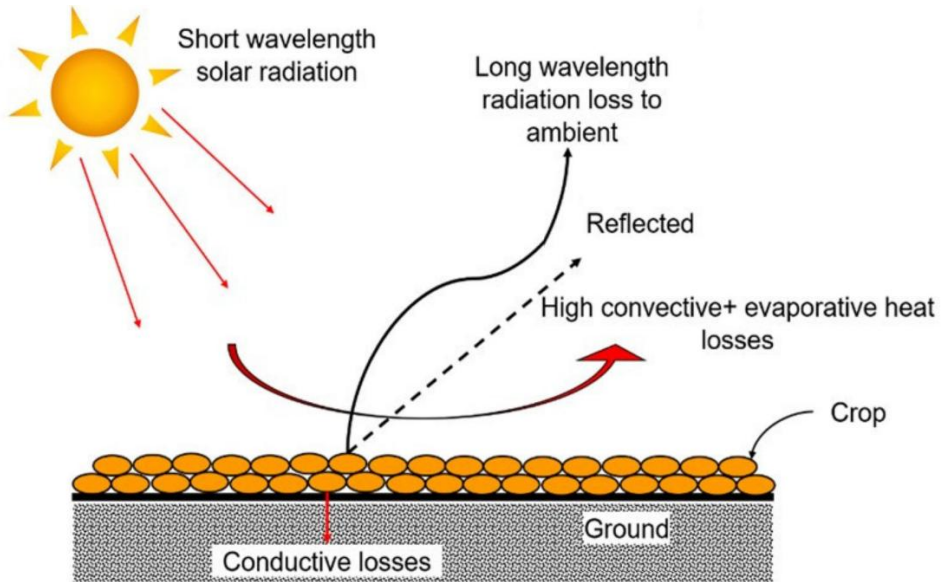


Fig. 1. Open sun drying on the ground covered with a mat [8].

Open sun drying on the ground covered a mat as seen in Figure 1 has the disadvantage of possibility of heat loss by conduction. Furthermore, there is the possibility of water evaporation from the ground surface, which will absorb nearby heat energy and increase the water content in the air surrounding the crop, thereby reducing the ability of the surrounding air to absorb water vapor from the crop being dried. [8, 9, 10].

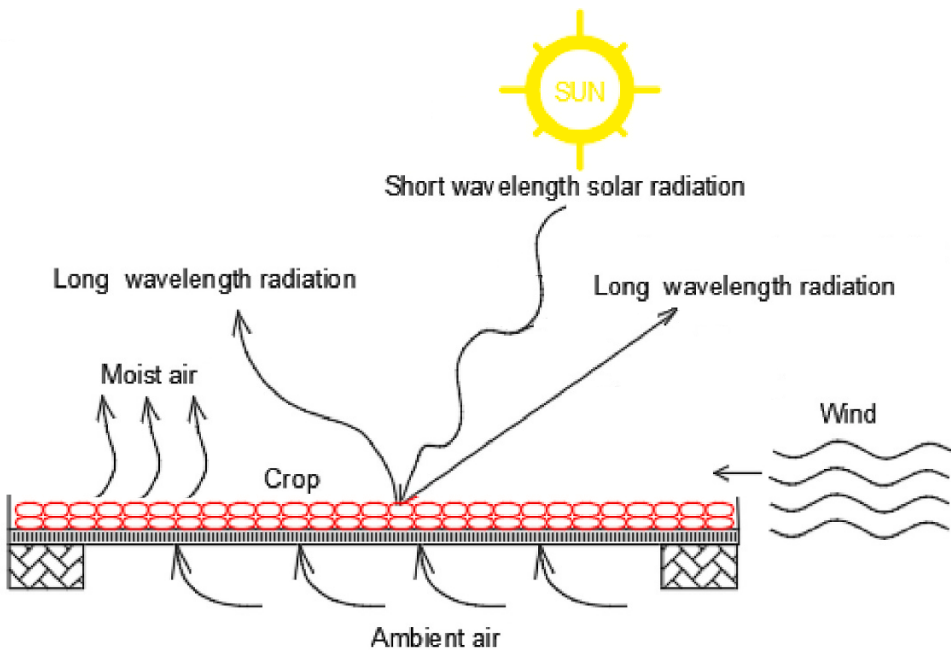


Fig. 2. Open sun drying process on perforated rack or woven bamboo, adapted from [11].

Open sun drying process using an perforated rack or woven bamboo as seen in Figure 2 would allow the air from below and beside of the crop to flow and come into contact with

the material and absorb the material's water content. The heat source from sunlight in the form of short waves will be absorbed by the crop, some reflected, some will be released in the form of long waves. The energy utilized will be used to evaporate the material's water content. Evaporation of water from the ground under the perforated rack will affect the absorption of drying air through the crop [11,12].

Drying on an aluminium pan heats the coffee peels more quickly than drying on perforated rack. The coffee peels not only receives direct heat from the sun, but the coffee peels also experience conductive heating from the aluminium pan surface, which absorbs heat energy from the sunlight (Figure 3). The additional heating from the aluminium pan speeds up the drying process. The coffee peels are dried as if on a hot metal plate. [13, 14].

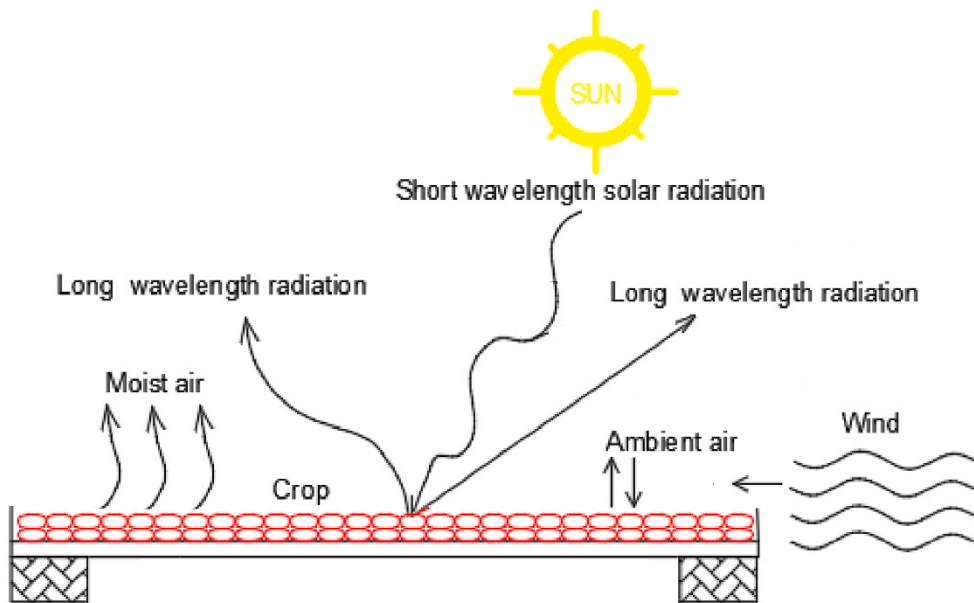


Fig. 3. Open sun drying process on aluminium pan, adapted from [11].

Based on Figure 3, it can be seen that drying using an aluminium pan allows for the provision of protective air from wind or from the surface of the pan, which moves naturally. Natural air movement occurs when the air in contact with the surface of the aluminium pan is heated, causing its density to decrease. The low density causes the air to rise and be replaced by air with a higher density, which will also rise after being heated like the previous air. Heating the air will lower its relative humidity, thereby increasing the air's ability to absorb water vapor from the products. [15, 16]

3.2 Drying Rate

The results of observations of the decrease in materials mass during drying of coffee peels using sunlight on an aluminium pan were analyzed to determine the drying rate. The drying rate of the coffee peels on the first day is presented in a graph as shown in Figure 4.

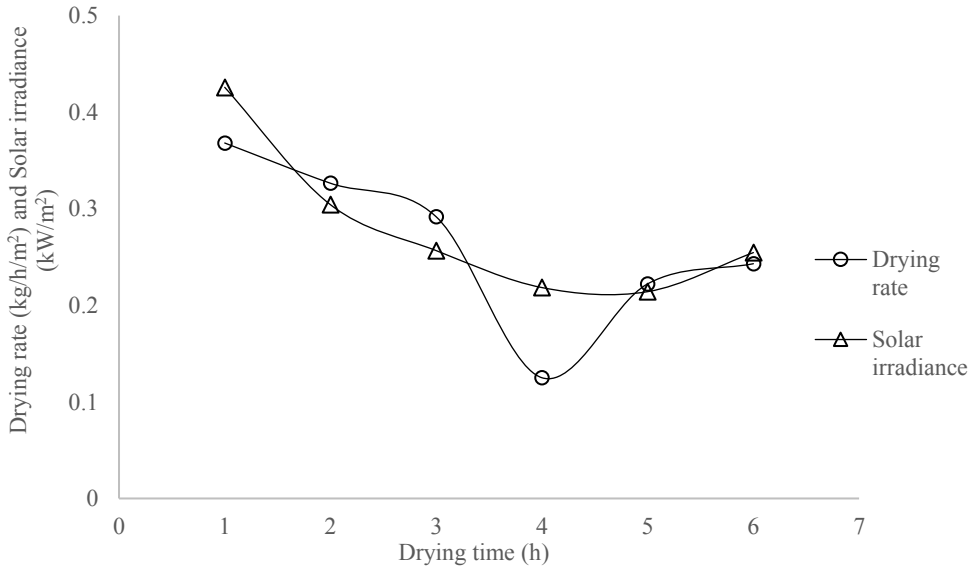


Fig. 4. Drying rate and solar irradiance in the 1st day drying process.

The drying rate as in Figure 4 is quite high about 0.33 kg/h/m² at the beginning of the drying process. This is because the material's moisture content is still very high and is also supported by sufficient solar irradiance. Decreasing solar irradiation also reduces the drying rate, as shown in Figure 4. In the fourth hour, there is a very significant decrease in the drying rate. Significant decrease in drying rate caused by light rain at that time, so the drying process was stopped for about 25 minutes. Drying on the first day only lasted about 6 hours. Rain also occurred at the 7th hour drying process, so drying process was stopped and continued on the second day. The drying rate of the coffee peels on the second day is presented in a graph, as shown in Figure 5.

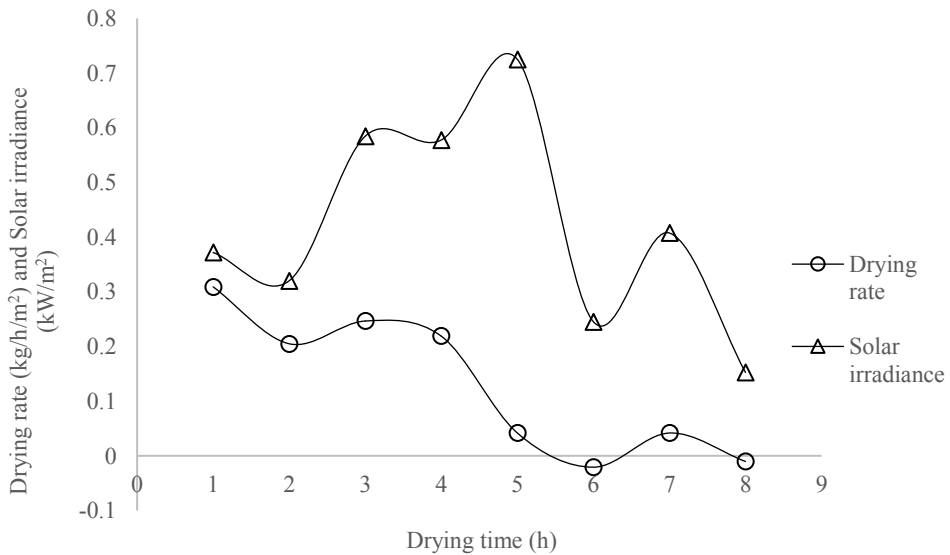


Fig. 5. Drying rate and solar irradiance in the 2nd day drying process.

Based on Figure 5, it can be seen that the drying rate is still affected by solar irradiance. That is indicated by the increasing drying rate as solar irradiance increases. However, the drying rate on the second day is lower than the first day and begins to decrease at the 4th hour. The drying rate decreases because the water content of the dried coffee peels is already quite low and the drying process has reached its final stage. The final drying rate reaches is $0.04 \pm 0.01 \text{ kg/h/m}^2$. That is also indicated by the negative drying rate values at the 6th and 8th hours. A negative drying rate indicates that the dried material does not release water content, but instead absorbs water vapor. That condition can occur when the material's moisture content during drying is so low that it has the potential to absorb water vapor from the ambient air. That usually occurs at the end of the drying process. [17, 18].

3.3 Moisture content

The water content of cascara dried using solar energy on aluminium trays and using perforated rack was analyzed using gravimetric and oven methods based on AOAC 2005. The cascara water content data is presented in a graph as in Figure 6.

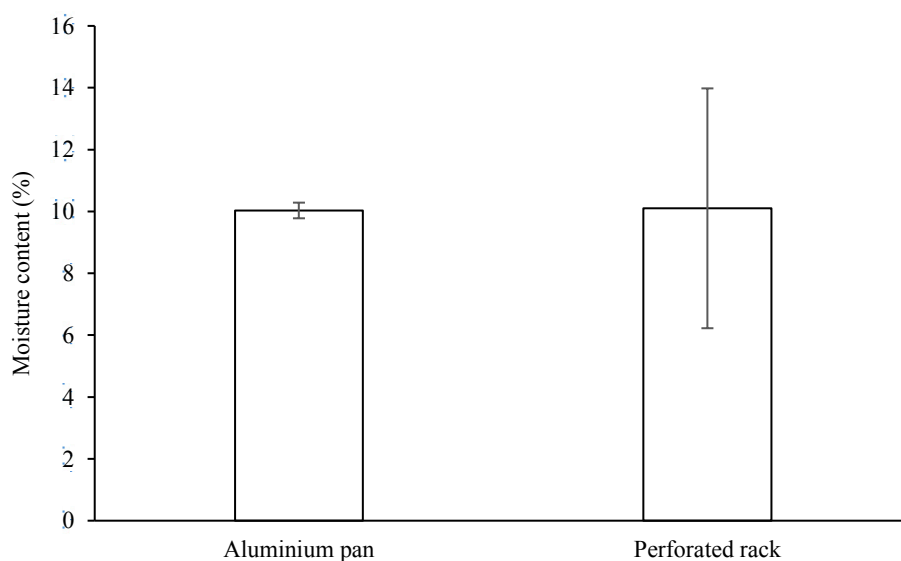


Fig. 6. Moisture content of dried cascara.

Based on Figure 6, it can be seen that the water content of cascara dried using aluminium pans is $10.01 \pm 0.25\%$ (wet basis). The water content of cascara is low enough to inhibit the growth of microorganisms that can damage the quality of dried cascara during the storage process. Based on the standard deviation, the water content value is also more uniform when compared to the results of cascara drying using perforated rack or woven bamboo, which has a water content value of $10.1 \pm 3.87\%$ (wet basis) [19, 20].

3.4 Drying efficiency

Drying efficiency using solar energy is the ratio of the energy required to evaporate the water content of the material to the energy from solar irradiation. The drying efficiency of coffee peels using aluminium pans is presented in a graph like Figure 7.

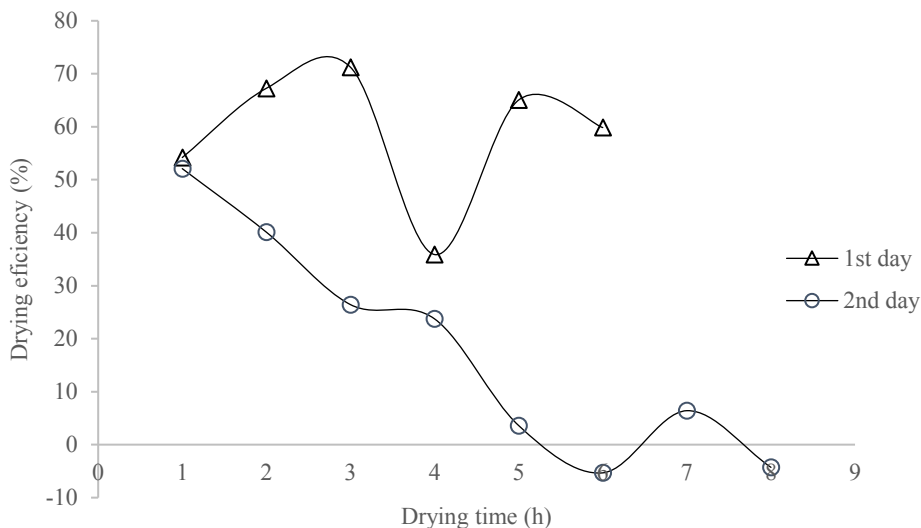


Fig. 7. Drying efficiency of dried cascara.

Based on Figure 7, it can be seen that drying efficiency on the first day, or at the beginning of the drying process, is quite high about 67.26%. That is because the water content in the coffee peels is still high, making them easily evaporated. Drying efficiency on the first day dropped drastically at the 4th hour due to light rain for about 25 minutes. Drying efficiency at the end of the second day was low (about 3.6%) because the moisture content of the coffee peels was already low, making evaporation of the material very difficult, as indicated by the low drying rate and negative drying rate values.

Using aluminum pans for drying cascara shortens drying time compared to using perforated racks. The use of aluminum pans increases heat transfer by convection and conduction to the dried cascara. Cascara that sticks directly to the surface of the aluminum pan will receive heat by conduction from the surface of the aluminum pan. The part of the cascara that is not in direct contact with the surface of the aluminum pan receives heat by convection from the heated air on the surface of the aluminum pan and receives direct radiant heat from the sun. This condition makes the drying process faster when compared to using a perforated rack. [21, 22, 23].

4 Conclusions

The drying time for coffee husks into cascara using solar energy on an aluminium pan is 2 days. The drying rate is approximately 0.33 kg/h/m² at the beginning of the drying process and 0.04 ± 0.01 kg/h/m² towards the end of the drying process. The moisture content of the dried cascara is 10.01 ± 0.25%. The efficiency of the cascara drying process is around 67.26% at the beginning of the drying process and 3.6% towards the end of the drying process.

References

1. D. Zargustin, D. Harmaidi, N. Nurwati, N. Susi, Analysis of Indonesian Coffee Production, Area, and Consumption Trends in 2022-2026: Opportunities and Challenges in Maintaining the Sustainability of the National Coffee Sector. *Enrichment: Journal of Multidisciplinary Research and Development*, **2** (12) (2025)
<https://doi.org/10.55324/enrichment.v2i12.321>
2. Y. Pham, K. Reardon-Smith, S. Mushtaq, G. Cockfield, The impact of climate change and variability on coffee production: a systematic review, *Climatic Change*, **156** (4), 609-630 (2019)
<https://doi.org/10.1007/s10584-019-02538-y>
3. N. Komaria, Suratno, J. Prihatin, Sudarti, An analysis of innovation on the utilization of cascara by coffee farmers. In *Journal of Physics: Conference Series*, Vol. **1563**, No. 1, p. 012015, IOP Publishing (2020)
<https://doi.org/10.1088/1742-6596/1563/1/012015>
4. R.R. Rizkiansyah, Y. Mardiyati, A. Hariyanto, T. Dirgantara, (2023), Arabica Coffee Pulp Cellulose: Isolation, Morphology, and its Capabilities to be Modified into Cellulose Nitrate, In *BIO Web of Conferences* Vol. **77**, p. 01001, EDP Sciences (2023)
<https://doi.org/10.1051/bioconf/20237701001>
5. A. Heeger, A. Kosińska-Cagnazzo, E. Cantergiani, W. Andlauer, Bioactives of coffee cherry pulp and its utilisation for production of Cascara beverage. *Food chemistry*, **221**, 969-975 (2017)
<https://doi.org/10.1016/j.foodchem.2016.11.067>
6. V. Belessiotis, E. Delyannis, Solar drying. *Solar energy*, **85** (8), 1665-1691(2011)
<https://doi.org/10.1016/j.solener.2009.10.001>
7. W. Horwitz, G.W. Latimer (Eds.), *Official Methods of Analysis of AOAC International*, (AOAC International, Maryland 2006)
8. S. Gorjian, B. Hosseingholilou, L.D Jathar, H. Samadi, S. Samanta, A.A. Sagade, K. Kant, R. Sathyamurthy, Recent advancements in technical design and thermal performance enhancement of solar greenhouse dryers. *Sustainability*, **13** (13), 7025 (2021)
<https://doi.org/10.3390/su13137025>
9. T.R.F. Sinuhaji, S. Suherman, H. Hadiyanto, A. Ardan, S. Rahmawati, Evaluation and comparison of drying models in open sun drying and photovoltaic and LPG burner assisted hybrid solar drying system, *Case Studies in Chemical and Environmental Engineering*, **11**, 101104 (2025)
<https://doi.org/10.1016/j.cscee.2025.101104>
10. T. Varzakas, C. Tzia (Eds.), *Food engineering handbook: food process engineering*, (CRC Press, Boca Raton 2015)
<https://doi.org/10.1201/b17803>
11. B.V. Suresh, Y. Shireesha, T.S. Kishore, G. Dwivedi, A.T. Haghghi, E.R. Patro, Natural energy materials and storage systems for solar dryers: State of the art. *Solar Energy Materials and Solar Cells*, **255**, 112276 (2023)
<https://doi.org/10.1016/j.solmat.2023.112276>

12. A. A. El-Sebail and S.M. Shalaby. Solar drying of agricultural products: A review. *Renewable and Sustainable Energy Reviews*, 16 (1), 37-43 (2012)
<https://doi.org/10.1016/j.rser.2011.07.134>
13. R.T. Toledo, R.K. Singh, F. Kong, *Fundamentals of food process engineering*, (Springer, New York 2018)
<https://doi.org/10.1007/978-3-319-90098-8>
14. J.P. Holman, *Heat Transfer*, (McGraw-Hill, New York 2010)
15. D.E. Rahmanto and N. Nurhayati, Handling of frozen food products and dry food simultaneously, in *IOP Conference Series: Earth and Environmental Science* (Vol. **1485**, No. 1, p. 012003), IOP Publishing (2025).
<https://doi.org/10.1088/1755-1315/1485/1/012003>
16. M. Farrel, G.L. Race, *Practical Psychrometry*, (CIBSE Publication, London 2012)
17. R.P. Singh and D.R. Heldman, *Introduction to Food Engineering*, (Academic Press, Amsterdam, 2014)
<https://doi.org/10.1016/C2011-0-06101-X>
18. A.S. Mujumdar, *Handbook of Industrial Drying*, (CRC Press, Boca Raton 2014)
<https://doi.org/10.1201/b17208>
19. D. Hu, X. Liu, Y. Qin, J. Yan, R. Li, Q. Yang, The impact of different drying methods on the physical properties, bioactive components, antioxidant capacity, volatile components and industrial application of coffee peel, *Food Chemistry: X*, **19**, 100807 (2023)
<https://doi.org/10.1016/j.fochx.2023.100807>
20. S.D.R. Tampubolon, M.B. Seleleubajak, N. Nurhayati, Effect of Drying Method and Temperature on the Quality of Cascara Tea. *Agro Bali: Agricultural Journal*, **7** (2), 435-448 (2024).
<https://doi.org/10.37637/ab.v7i2.1818>
21. M. Kumar, S. Sansaniwal, P. Khatak, Progress in solar dryers for drying various commodities. *Renewable and Sustainable Energy Reviews*, **55**, 346-360 (2016)
<https://doi.org/10.1016/j.rser.2015.10.158>
22. E.K. Akpinar, Drying of mint leaves in a solar dryer and under open sun: modelling, performance analyses. *Energy conversion and management*, **51**(12), 2407-2418 (2010)
<https://doi.org/10.1016/j.enconman.2010.05.005>
23. P.K. Jangde, A. Singh, T. Arjunan, Efficient solar drying techniques: a review. *Environmental Science and Pollution Research*, **29** (34), 50970-50983 (2021)
<https://doi.org/10.1007/s11356-021-15792-4>