International Journal of Scientific Research in Science and Technology
Available online at : www.ijsrst.com
Print ISSN: 2395-6011 | Online ISSN: 2395-602X
doi : https://doi.org/10.32628/IJSRST52310412

Design And Implementation of Low-Cost Solar Dryer For Sun-Dried Guava Production

Asa Taufiqurrahman*[1], Heri Sutanto[2], Sri Widodo Agung Suaedy[3]
*[1]Magister of Energy, Diponegoro University, Semarang, Central Java, Indonesia
[2]Faculty of Science and Mathematics, Diponegoro University, Semarang, Central Java, Indonesia
[3]Faculty of Science and Mathematics, Diponegoro University, Semarang, Central Java, Indonesia

ARTICLEINFO

Article History:

Accepted: 02 July 2023
Published: 20 July 2023

Publication Issue
Volume 10, Issue 4
July-August-2023

Page Number
214-220

ABSTRACT

Crystal guava (Psidium guajava) is a commodity that is widely cultivated in Kebumen. Innovation is needed to increase its selling value, one of which is by producing dried guava. The production of dried guava can be achieved using a solar dryer. In this research, the design and testing of a low-cost solar dryer for producing dried guava were conducted. The main materials used were wood, aluminum pipes, aluminum foil as solar collectors, and solar panels to supply power to DC fans, thus enhancing drying efficiency. The energy analysis revealed that the average collector efficiency, drying efficiency, and specific energy consumption were 73%, 8.84%, and 0.182 kWh/kg, respectively, for the forced convection solar dryer (FCSD), and 42%, 4.61%, and 0.236 kWh/kg, respectively, for the natural convection solar dryer (NCSD). Moreover, in this research, the moisture content of guava, initially at 85%, decreased to 10.73% for FCSD and 25.05% for NCSD. The payback period for this project is estimated to be 1.79 years, enabling guava farmers to use this solar dryer to enhance the selling value of their products.

Keywords: Guava, Solar Dryer, Forced Convection, Drying Efficiency

I. INTRODUCTION

Fruit is a source of various vitamins, fibre, and minerals necessary for human health. The World Health Organization (WHO) recommends a daily minimum intake of 400 grams of fruits and vegetables [1]. Regular consumption of fruits and vegetables can reduce the risk of health issues such as heart attacks, strokes, and cancer. One practical way to obtain the nutritional benefits of fruit is by consuming dried fruit.

Drying is a long-standing preservation method for agricultural products, including fruits. The purpose of drying is to reduce water content, inhibiting the growth of microorganisms. Additionally, the drying process reduces the mass and volume of the product, making it suitable for storage and distribution.

Producers typically make fruit chips or dried fruit using direct sunlight through open sun drying or by employing a drying oven. However, open sun drying exposes the product to pollution, which can reduce its quality, and it often requires a lengthy drying time. On the other hand, using a drying oven necessitates significant investment and operational costs for large-scale production [2].

Crystal guava (Psidium guajava) is a prominent commodity in the southern coastal area of Kebumen Regency, particularly in Wergonayan Village, Mirit District. In this area, around 115,200 kg of crystal guava, valued at approximately IDR 806,000,000, is produced annually from a 6-hectare plantation [3]. Crystal guava is highly sought after due to its sweet taste reminiscent of pears. The growing production and demand for crystal guava present an opportunity to create dried guava as one of its processed products. This research aims to design and implement a cost-effective solar dryer using bamboo, a readily available material in the south coast of Kebumen Regency. The solar dryer will be tested using crystal guava as the primary sample. The goal is to develop an efficient and affordable drying method for crystal guava, serving as a reference for crystal guava farmers in Kebumen.

II. METHODS AND MATERIAL

A. Materials

The raw material used in this study is guava. It was sourced from guava farmers in Maduretno District, Buluspesantren, Kebumen Regency, as they belong to the guava farming community.

B. Design of dryer

The main components of the designed solar dryer are the solar collector and the drying chamber. Wood is used as the main material for the frame and body of the solar dryer. The solar collector serves as an absorber and collector of solar heat. The top of the solar collector is made of transparent fiber, while the inside is covered with aluminum foil. Additionally, there is an aluminum pipe that supplies hot air into the chamber. The drying chamber is equipped with three shelves for placing the items to be dried. At the top, there is an air circulation hole that utilizes a DC fan powered by electricity from solar cells.

C. Drying process

The experiments were conducted in the Murtirejo District, Kebumen Regency. The coffee beans used in this process had an initial moisture content of 80%-85% (dry basis). Two drying methods were employed in this experiment: natural convection drying without a DC fan and forced convection drying with a DC fan. Approximately 200 grams of guava were placed on the aluminum trays and dried from 08:00 a.m. to 04:00 p.m. over the course of two days for each experiment. The weight of the sample and the temperature of the solar collector and each tray were measured every 60 minutes.

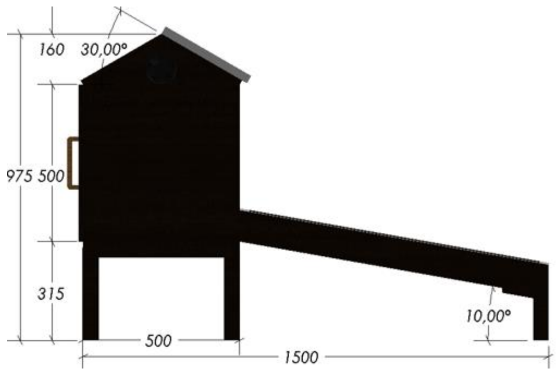

Figure 1: Design of Solar Dryer

Figure 2: Implementation of Solar Dryer

TABLE I
SPECIFICATIONS OF SOLAR DRYER

Components	Specifications
Solar Collector	
Type	Evacuated tube
Area	0.5 m^2
Transparent Fiber	0.5 mm
Black body	Wood, 1.5 cm
Degree of inclination	10°
Drying Chamber	
Chamber size	0.5 x 0.5 x 0.5 m
Tray area	0.49 x 0.49 m
Exhaust	Diameter: 11 cm
Blower	
Capacity	12 V 0.25 A
Velocity	1500 rpm

III.RESULTS AND DISCUSSION

A. Solar Radiation (I_{sr})

The natural (NCSD) and forced convection (FCSD) experiments were conducted consecutively from march 7 to march 8, and march 14 to march 15, 2023, at Murtirejo District, Kebumen Regency. The data were conducted from 8.00 am to 4.00 pm. Based on the data presented in table 2 [4], It can be observed that there is solar radiation in W/m^2 values at all times, indicating that the experiments were conducted on sunny days. On the other hand, Figure 3 (red and blue lines) illustrates the disparity in radiation between the NCSD and FCSD experiments. The average difference in solar radiation values is 7.7 W/m^2, which is considered negligible and unlikely to cause significant variations in the characteristic parameters between the two dryers.

B. Actual heat supply (Q_i)

The heat input to the collector (Qi) was determined by multiplying the solar radiation (I_{sr}) by the area of the solar collector [5]. In this experiment, the area of the solar collector was 0.5 m^2. Figure 3 (yellow and grey lines) demonstrates that Q_i follows the same trend as the solar radiation data, as both Q_i and solar radiation are directly correlated. The average and maximum Q_i values for NCSD and FCSD are 348.9 W and 345 W, and 496.2 W and 501.8 W, respectively.

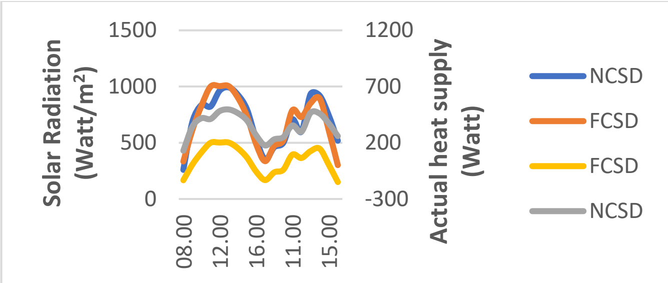

Figure 3: Solar Radiation and Actual Heat Supply for NCSD and FCSD

C. Temperature distribution

Temperature measurements were taken at various points around the solar dryer, including the ambient temperature (T_{amb}), solar collector chamber (T_{col}), solar collector output (T_o), tray 1 (T_1), tray 2 (T_2), tray 3 (T_3), and output chamber (T_{out}). The highest temperature recorded was in the solar collector. For NCSD, the highest temperature reached 60.1°C, while for FCSD, it was 53.8°C. Figures 4 and 5 illustrate the temperature decrease from the solar collector to the output of the solar dryer due to heat loss. On average, there was a temperature increase of around 7.3°C for NCSD and 7.4°C for FCSD compared to the ambient temperature. During the NCSD experiment, with an average ambient temperature of 37°C, the average temperature in the drying chamber was 41.7°C. For FCSD, the average temperature in the drying chamber was 37.2°C, with an average ambient temperature of 32.5°C. The temperature difference between the ambient temperature and the drying chamber was greater for FCSD compared to NCSD.

While the temperature values in natural and forced convection did not show a significant difference, forced convection helped to distribute heat more evenly throughout the fluid, resulting in a more uniform temperature distribution [6].

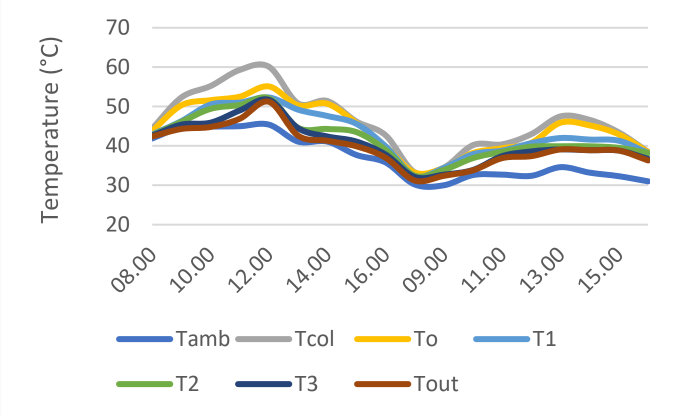

Figure 4: Natural Convection Solar Dryer Temperature Distribution

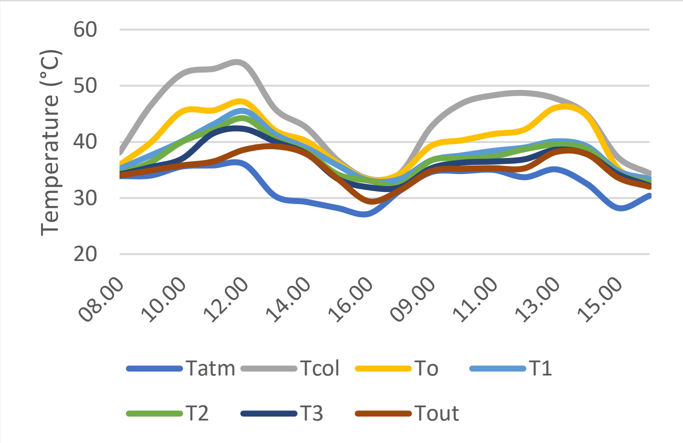

Figure 5: Forced Convection Solar Dryer Temperature Distribution

D. Useful Heat Output (Q_u)

The useful heat output is calculated by multiplying the mass flow rate by the specific heat capacity and the temperature difference between the collector output and the ambient temperature. The mass flow rate is determined using the density and air velocity through the aluminium pipe [7]. The air velocity is assumed to be the average wind velocity during the experiment, which is 5.5 m/s for NCSD and 9.42 m/s for FCSD, considering the wind velocity generated by the DC fan. Figure 6 illustrates the useful heat output of NCSD and FCSD. The value of the useful heat output in FCSD is significantly higher than in NCSD. This is due to the higher mass flow rate in FCSD, which is a result of the blower that accelerates the airflow [8].

$$Q_u = m_a c_{pa}(T_{atm} - T_o)$$

$$m_a = \rho_{air}\, v_{air}\, A$$

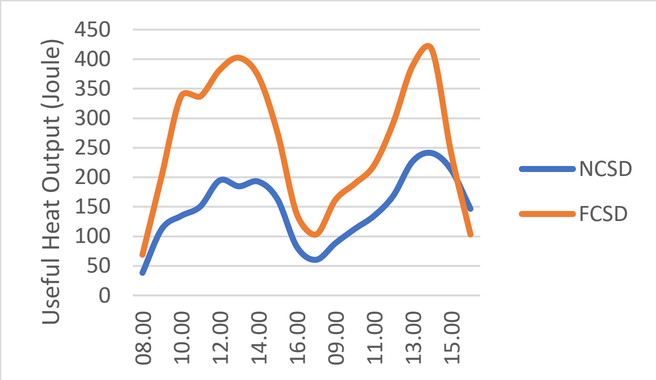

Figure 6: Useful Heat Output of NCSD and FCSD

E. Collector efficiency (η_{col})

The solar collector efficiency is calculated by dividing the useful heat output by the actual heat supply [9]. The average solar collector efficiency for NCSD is 42%, while for FCSD it is 73%. This indicates that the use of DC fans increases the collector efficiency by enhancing the mass flow rate.

The collector efficiency of FCSD can surpass the collector efficiency reported in previous studies conducted in India that utilized more expensive aluminium plate materials [10]. Figure 7 depicts the efficiency of the solar collectors in NCSD and FCSD.

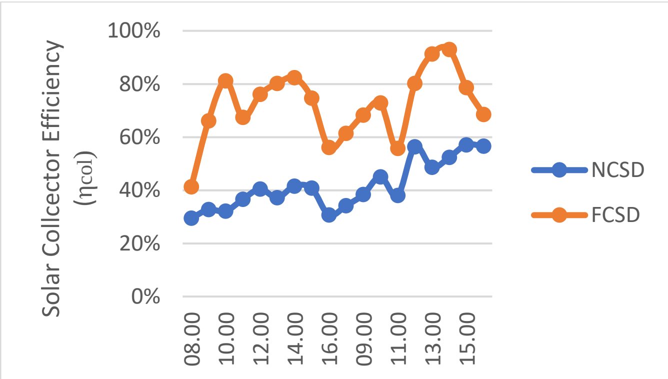

Figure 7: Solar Collector Efficiency of NCSD and FCSD

F. Drying efficiency (η_{dry})

Drying efficiency is defined as the ratio of the latent heat of moisture evaporation in the sample to the energy required for evaporating moisture from free water [11]. The drying efficiency (η_{dry}) for NCSD and FCSD was estimated and presented in Figure 8.

$$\eta_{dry} = \frac{m_w L_w}{Q_i}$$

The average η_{dry} values are 4.61% and 8.84% for NCSD and FCSD, respectively. The highest drying efficiency value was observed on the first day due to the initially high moisture content in the guava.

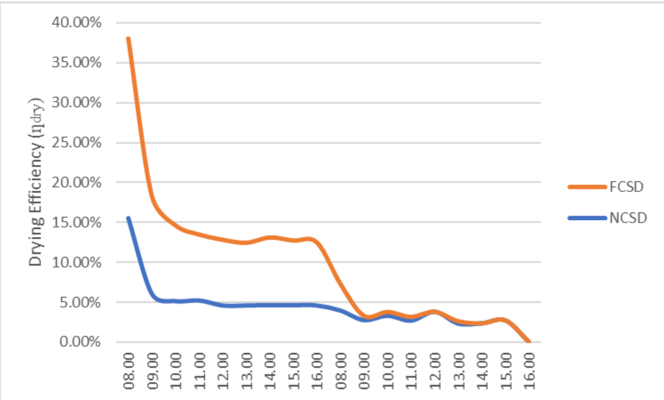

Figure 8: Drying Efficiency of NCSD and FCSD

G. Specific energy consumption (SEC)

Specific Energy Consumption (SEC) is a metric used to assess the energy efficiency of a system or device [12]. In the context of a solar dryer, SEC refers to the amount of energy needed to dry a given quantity of material per unit of drying area or mass. A lower SEC value indicates a more energy-efficient solar dryer.

In this experiment, the SEC values were 0.236 kWh/kg for NCSD and 0.182 kWh/kg for FCSD. These values are relatively low, suggesting that the drying efficiency of the solar dryer in this study is comparable to or even better than previous solar dryer research that utilized aluminium materials [13].

H. Moisture content

Figure 9 illustrates the reduction in water content on a dry basis over a period of 16 hours. The drying process using FCSD results in a faster decrease in water content due to the higher airflow compared to NCSD. With an initial moisture content of 85% [14] it decreases to 10.73% for FCSD and 25.05% for NCSD.

The drying outcomes are depicted in Figure 10, showcasing the distinctions between direct sun drying, NCSD, and FCSD. The results of direct sun drying exhibit a paler colour compared to FCSD and NCSD. Furthermore, the water content in FCSD and direct sun drying is lower than in NCSD, indicating that NCSD did not achieve optimal dryness.

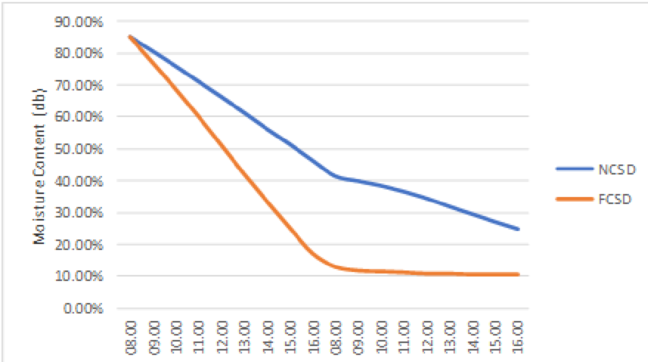

Figure 9: Moisture Percentage of *Psidium guajava* in NCSD and FCSD

Figure 10: Comparison Result Between Direct Sun Drying, NCSD, and FCSD

I. Economic analysis

The capital cost of this solar dryer is $92.6, and it has a maximum production capacity of 0.8 kg over a period of 16 hours (2 days). Assuming there are 240 sunny days, it can produce 96 kg of fresh guava, which will result in 25 kg of sun-dried guava. In Kebumen Regency, the price of fresh guava is

$0.33/kg, while in the international market, the price of dried guava is $3.43/kg.

Comparing the investment capital to the annual results, the payback period is calculated to be 1.79 years. Additionally, the solar dryer has a lifespan of 5 years. Consequently, guava farmers can utilize this solar dryer to increase the selling value of their products.

IV. CONCLUSION

In the experiments conducted to compare the drying of guava using direct sun drying and indirect solar dryers with natural convection (NCSD) and forced convection (FCSD), data on solar radiation (I_{sr}), actual heat supply (Q_i), and temperature distribution were collected. The analysis focused on collector efficiency (η_{col}), drying efficiency (η_{dry}), specific energy consumption (SEC), moisture content, and economic analysis. Based on the findings, the following conclusions can be drawn:

- The average efficiency of the solar collector (η_{col}) at NCSD is 42% while at FCSD is 73%. This means that the use of DC fan increases collector efficiency because it increases the mass flow rate.
- The average drying efficiency (η_{dry}) is 4.61% for NCSD and 8.84% for FCSD. The use of a DC fan also improves drying efficiency.
- The specific energy consumption (SEC) values are 0.236 kWh/kg for NCSD and 0.182 kWh/kg for FCSD.
- The moisture content of guava, initially at 85%, decreases to 10.73% for FCSD and 25.05% for NCSD.
- The economic analysis of the low-cost solar dryer design indicates a payback period of 1.79 years, with a projected lifetime of 5 years.

V. REFERENCES

[1]. World Health Organization, “Increasing fruit and vegetable consumption to reduce the risk of noncommunicable diseases,” 2019. https://www.who.int/elena/titles/fruit_vegetables_ncds/en/.

[2]. A. D. Saputra, R. Amalia, M. E. Yulianto, and V. Paramita, “Effect Of Banana Types on Oven Drying Process For Crispy Banana Production,” J. Vocat. Stud. Appl. Res., vol. 2(2), no. October, pp. 20–24, 2020.

[3]. M. Y. Krisnha, “Gus Yazid Panen Raya Jambu Kristal Kebumen,” Lintas24.com, 2019. https://lintas24.com/gus-yazid-panen-raya-jambu-kristal-kebumen.

[4]. Asosiasi Energi Surya Indonesia, “Indonesia Solar Map,” 2023. Indonesiasolarmap.com.

[5]. V. R. Mugi and C. V.P., “Comparison of drying kinetics, thermal and performance parameters during drying guava slices in natural and forced convection indirect solar dryers,” Sol. Energy, vol. 234, no. December 2021, pp. 319–329, 2022, doi: 10.1016/j.solener.2022.02.012.

[6]. C. Brasil Maia, A. Guimarães Ferreira, L. Cabezas-Gómez, S. de Morais Hanriot, and T. de Oliveira Martins, “Simulation of the Airflow Inside a Hybrid Dryer,” Int. J. Res. Rev. Appl. Sci., vol. 10, no. March, pp. 382–389, 2012, [Online]. Available: http://arpapress.com/Volumes/Vol10Issue3/IJRRAS_10_3_02.pdf.

[7]. D. Befikadu, A. Umar, and S. Abera, “Design development and performance evaluation of solar dryer for drying onion used as powder in food,” Artic. Int. J. Sci. Basic Appl. Res., vol. 38, no. 1, pp. 231–243, 2018, [Online]. Available: http://gssrr.org/index.php?journal=JournalOfBasicAndApplied.

[8]. L. V. Erick César, C. M. Ana Lilia, G. V. Octavio, S. S. Orlando, and D. N. Alfredo, “Energy and exergy analyses of a mixed-mode

solar dryer of pear slices (Pyrus communis L)," Energy, vol. 220, 2021, doi: 10.1016/j.energy.2020.119740.

[9]. M. Z. Hossain, M. M. Alam, M. F. Bin Hossain, M. S. H. Sarker, M. A. Awal, and N. Jahan, "Performance evaluation of a cabinet solar dryer for drying red pepper in Bangladesh," J. Agric. Eng., vol. 49, no. 2, pp. 100–109, 2018, doi: 10.4081/jae.2018.774.

[10]. V. R. Mugi and V. P. Chandramohan, "Energy, exergy, economic and environmental (4E) analysis of passive and active-modes indirect type solar dryers while drying guava slices," Sustain. Energy Technol. Assessments, vol. 52, no. PC, p. 102250, 2022, doi: 10.1016/j.seta.2022.102250.

[11]. M. Ssemwanga, E. Makule, and S. I. Kayondo, "Performance analysis of an improved solar dryer integrated with multiple metallic solar concentrators for drying fruits," Sol. Energy, vol. 204, no. June 2019, pp. 419–428, 2020, doi: 10.1016/j.solener.2020.04.065.

[12]. M. C. Gilago, V. R. Mugi, and V. P. Chandramohan, "Investigation of exergy-energy and environ-economic performance parameters of active indirect solar dryer for pineapple drying without and with energy storage unit," Sustain. Energy Technol. Assessments, vol. 53, no. PC, p. 102701, 2022, doi: 10.1016/j.seta.2022.102701.

[13]. M. C. Gilago, V. Reddy Mugi, and V. P. Chandramohan, "Energy-exergy and environ-economic (4E) analysis while drying ivy gourd in a passive indirect solar dryer without and with energy storage system and results comparison," Sol. Energy, vol. 240, no. April, pp. 69–83, 2022, doi: 10.1016/j.solener.2022.05.027.

[14]. M. A. Ali, Y. A. Yusof, N. L. Chin, and M. N. Ibrahim, "Effect of different drying treatments on colour quality and ascorbic acid concentration of guava fruit," Int. Food Res. J., vol. 23, no. April 2018, pp. S155–S161, 2016.

Cite this article as :

Asa Taufiqurrahman, Heri Sutanto, Sri Widodo Agung Suaedy, "Design And Implementation of Low-Cost Solar Dryer For Sun-Dried Guava Production ", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 10 Issue 4, pp. 214-220, July-August 2023. Available at doi : https://doi.org/10.32628/IJSRST52310412
Journal URL : https://ijsrst.com/IJSRST52310412