

RESEARCH ARTICLE



Performance of paddy dryer with screw conveyor assisted parabolic cylinder collector as thermal generator

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Abstract

Objectives: This study aims to develop better solar dryer for paddy drying. **Methods and Analysis:** The design and fabrication of a parabolic cylinder type collector-drying unit has been developed. Paddy is dried by the variation which took place into four batches starting from batch 1 (08:30 - 09:20), batch 2 (09:30 - 10:10), batch 3 (10:20 - 11:10) and batch 4 (11:40 - 12:20) Western Indonesia Time (GMT +7), with a capacity of 5 kg of paddy/batch and solar radiation is in the range of 408.5 - 547.2 Watt/m². The highest irradiation takes place in batch 2 with the maximum temperature inside the dryer reaching 74°C. **Findings:** Overall the experiments achieved that paddy temperature are in the range of 43 - 45°C, with the shortest drying time achieved in batches 2 and batch 4 i.e. 40 minutes. Thermal efficiency are in the range of 37.91% - 50.35%, SEC of 5.318 - 7.042 MJ/kg H₂O evaporated and drying rate of 1.06 - 1.38 kg/hrs. Thus, this solar dryer is more effective than industrial inclined bed dryer or the industrial horizontal rotary dryer. **Novelty:** The solar dryer using a parabolic cylinder type solar collector with a screw conveyor has been designed which can reduce drying time and moisture content better.

Keywords: Solar dryer; parabolic collector; paddy; efficiency

1 Introduction

Paddy is the main source of carbohydrate for Indonesian people. According to statistics, in 2019 for a national planting area of 10.68 million hectares, 54.60 million tons of paddy were obtained⁽¹⁾. Thus, the land production capacity is 5.1 tons of paddy/Ha or 2.9 tons of rice/Ha. Data from the Central Statistics Agency in collaboration with Indonesia Agency for the Assessment and Application of Technology (BPPT) has mapped national paddy production in 2018 - 2019 as presented in [Figure 1](#). This optimum production occurs in March and decreases at the end and beginning of the year. In conditions where production is abundant

and the weather is erratic or cloudy, almost all agricultural products need intense attention in terms of their preservation. The most effective preservation to date is through drying. Specifically, in Indonesia the method of drying agricultural products is still using a direct drying system.

As such, newly harvested paddy generally has a moisture content of around 28 - 35%⁽²⁾ and it must be dried up to a certain moisture content that is safe for storage. Based on grain quality standards set by SNI 01-0224-1987, the maximum paddy moisture content is 14%. Research on the effect of variations in artificial drying temperature on paddy quality has proven that to maintain paddy quality in terms of fatty acid levels, it is recommended that drying temperatures are below 45°C if the initial moisture content is less than 21.36%⁽³⁾.

The effect of drying using a passive solar dryer on the quality of paddy has been proven to provide better quality in terms of the degree of whiteness, aroma, amylose, thiamine, and lysine levels are the same as the quality of paddy which is dried by direct drying⁽⁴⁾.

In Indonesia, the process of drying paddy is still done by direct sun drying. This conventional method has disadvantages such as less representative cleaning, wider drying area, and longer drying time in dry season approximately 4 – 5 days.

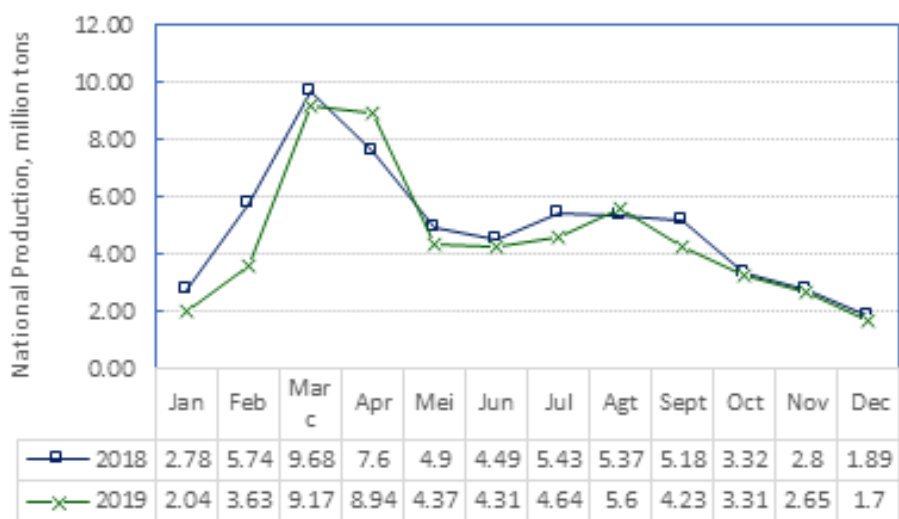


Fig 1. Indonesian national paddy production data 2018 – 2019⁽¹⁾

Drying is a process of evaporation (water expenditure) that is very intense in consuming energy. Therefore, the use of renewable energy as an energy source, especially for drying agricultural products continues. Several previous studies have shown that solar thermal energy is quite effective to be utilized in paddy drying technology.

Drying paddy at low temperatures (26-34°C) and RH (19-68%) have proven that RH more significantly influences the rate of drying and quality of paddy (color) can be maintained⁽⁵⁾. This method is considered economically ineffective because to reduce RH to reach 19% requires quite expensive energy unless done thermochemically namely with the help of adsorbents.

One of other artificial dryer has been carried out for paddy drying using industrial rotary horizontal dryer. The results shown that using that type of dryer has the specific energy consumption (electrical) between 5.5 -17.41 MJ/kg. water evaporated⁽⁶⁾.

Solar drying technology for agricultural product was develop in many countries in Asian and sub-Saharan African. Numerous types or designs of solar dryers can be constructed according to the budget, location, and requirement of the materials to be dried⁽⁷⁾. An inflatable solar dryer (ISD) was developed based on adaptations of the Hohenheim-type solar tunnel dryer to improved postharvest handling of paddy. The disadvantage of the dryer is that grain temperature were higher in top layer than in bottom layer⁽⁸⁾. Operation of rotary dryer for paddy drying

to reduce moisture content of 13% to 8% (% w.b) were carried out. The test result showed that the specific energy consumption was 10.48 MJ/ kg water evaporated⁽⁹⁾.

Solar thermal technology with concentric collector (cylinder or parabolic) type as heat generator has been developed for various purposes such as cooking, refrigeration systems and drying^(10–12).

In a parabolic or cylindrical (arch) type collector, sunlight is collected using a reflective surface which is then forwarded/directed to a focal point (f). As a result of this concentration of sunlight, causing temperature at the focal point becomes optimal. This type of heat collection technology is capable of producing temperatures reaching temperatures in the range of 60 - 250°C⁽¹³⁾. The relatively large range of temperature performance in this type of parabola collector allows users to operate at low to high temperatures, and this is largely determined by the design and type of material used for the system.

In this research, the design and fabrication of a parabolic cylinder type collector-drying unit have been carried out to dry paddy with a maximum drying temperature of 60°C. With a relatively low drying temperature limit, the materials used to build reflectors are also relatively commonly available in the market. Manufacturing results are then evaluated through trials to dry the newly harvested paddy.

2 Material and Methods

2.1 Preparation

The material to be dried is IR-64 Paddy from paddy fields in Deli Serdang Regency, North Sumatera, Indonesia. The initial water content of paddy is 28% (wet basis) and will be dried up to a water content of 14% (w.b).

Parabolic collector type solar dryers have been designed for 5 kg/batch capacity. Dryers are cylindrical tubes with a diameter of 20 cm and a length of 200 cm. Inside it is equipped with a screw conveyor that functions as a driving force for the flow of paddy and a stirrer so that the process of heat transfer and mass is evenly distributed on a moving paddy pile. The specifications of the screw conveyor are 19 cm in diameter, the number of leaves is 13, the distance between leaves is 15.3 cm, as shown in Figure 2.

The satellite dish collector is designed to reflect solar radiation to the focal point where the dryer is placed. The collector has dimensions of diameter, length, height, and location of the focal point (f) respectively 150 cm, 200 cm, 60 cm, and 23.4 cm. The surface of the collector is coated with a reflector made of aluminum sticker material which has a thickness of 0,4 mm (Figure 2).

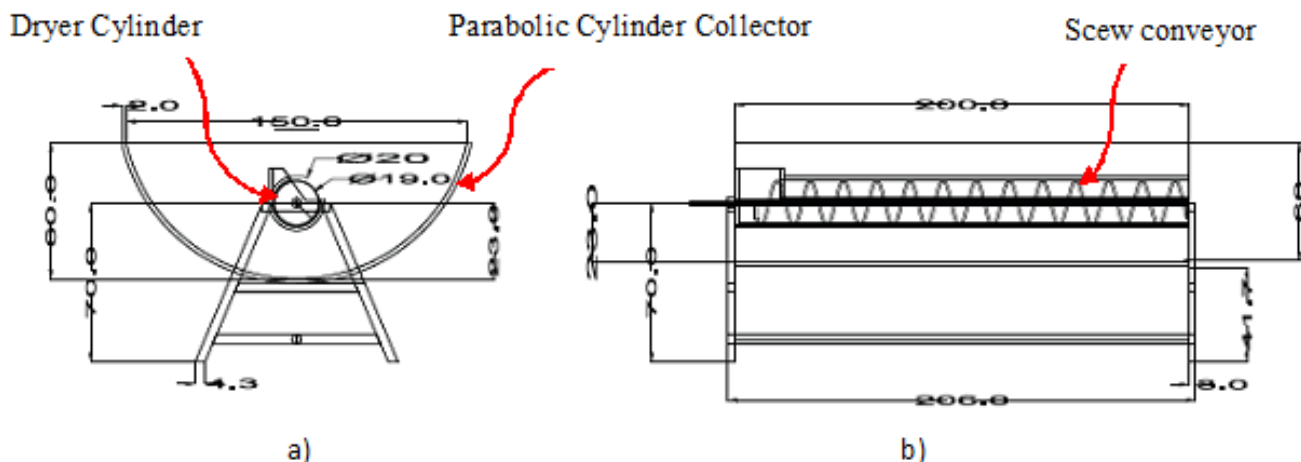


Fig 2. Design of paddy solar dryer with cylinder parabolic type collector

2.2 Research set-up

The experiment was conducted during December 2019 starting from 10:00 until 16:00 WIT (GMT +7). The data were collected at 10-minute intervals, with the measuring instrument used in this research is Solar Power Meter to measure the intensity of solar radiation with units (W/m²) and temperature measurements using temperature data loggers connected to thermocouples at 4 (four) points T₁, T₂, T₃ and T₄, respectively are: temperature inside of dryer, temperature outside of dryer, paddy temperature and ambient temperature

When drying starts, the screw conveyor rotation is set at 23 rpm, and weight changes in paddy weighed every time the paddy comes out of the drying cylinder chamber using a digital scale with a precision of 0.01 grams. The test is carried out 3 times with a paddy capacity of 20 kg, which is done in stages, i.e.: every 5 kg. Data collection in this graph is done by drying one time every 1 day of testing.

The performance of the dryer is determined by calculating the thermal efficiency which is the ratio of used energy (Q_{used}) to the energy received (in). The effectiveness of paddy drying is measured by calculating the specific energy consumption (SEC), the specific moisture evaporation rate, and the drying rate. All of these Units are calculated using the following equation:

$$\text{Efficiency, \%} = \frac{Q_{\text{used}}}{((I.A.\Delta t) + Q_{\text{conveyor}})} \times 100 \tag{1}$$

The value of the used energy (Q_{used}) is based on the following equation, (Panwar et al., 2012):

$$Q_{\text{used}} = \frac{(m_{\text{padi}} \times C_p \times (T_{\text{out}} - T_{\text{in}})) + m_w \times h_{fg}}{\Delta t} \tag{2}$$

$$SEC = \frac{\text{Total enegy input}}{H_2O \text{ evaporated}}, \text{ MJ/kg}_{H_2O \text{ evaporated}} \tag{3}$$

$$SMER = \frac{1}{SEC} \tag{4}$$

$$\text{Drying Rate, DR} = \frac{\text{total } H_2O \text{ eavaorated}}{\text{unit time}}, \text{ kg/hr} \tag{5}$$



Fig 3. Solar dryers with cylindrical parabolic collectors for paddy drying

3 Results and Discussion

3.1 Solar radiation profile toward temperature

Drying takes place from 08.30 to 12.20 WIT, with an initial paddy weight of 5 kg/batch. Based on controlling the final weight gain, which is 4.1 kg to get the final moisture content of 14%, then on the first day, 4 (four) drying batches were carried out 4 as shown in Figure 3. The test has shown that the highest average radiation intensity was achieved in batch 2 which is 547.2 Watt/m², while the lowest radiation intensity is batch 1 which is 408.5 Watt/m². In batch 1 (morning) the intensity of radiation, dryer temperature (outer and inner walls), paddy temperature and ambient temperature continue to increase over time. In batch 1, a portion of the radiation intensity that is converted to thermal energy is used to increase the temperature of the drying chamber and then to evaporate, so it takes longer drying time than in the next batch.

In batch 3 (10:20 - 11:10) the sky getting cloudy that causes the radiation intensity to decrease, affecting the temperature drop in the drying chamber. Although at certain times the weather conditions are cloudy, the decrease in temperature in the drying chamber is never below 45°C. This indicates that concentric collectors (parabolic) are more effective in maintaining and reflecting solar radiation.

The higher the radiation intensity, the thermal energy conversion received by the drying chamber is also higher, this can be seen in the average temperature profile in the dryer in batches 2 and batch 4 where the drying chamber temperature reaches 74 - 71°C. With the higher temperature in the drying chamber, the heat transfer process in paddy is also more effective.

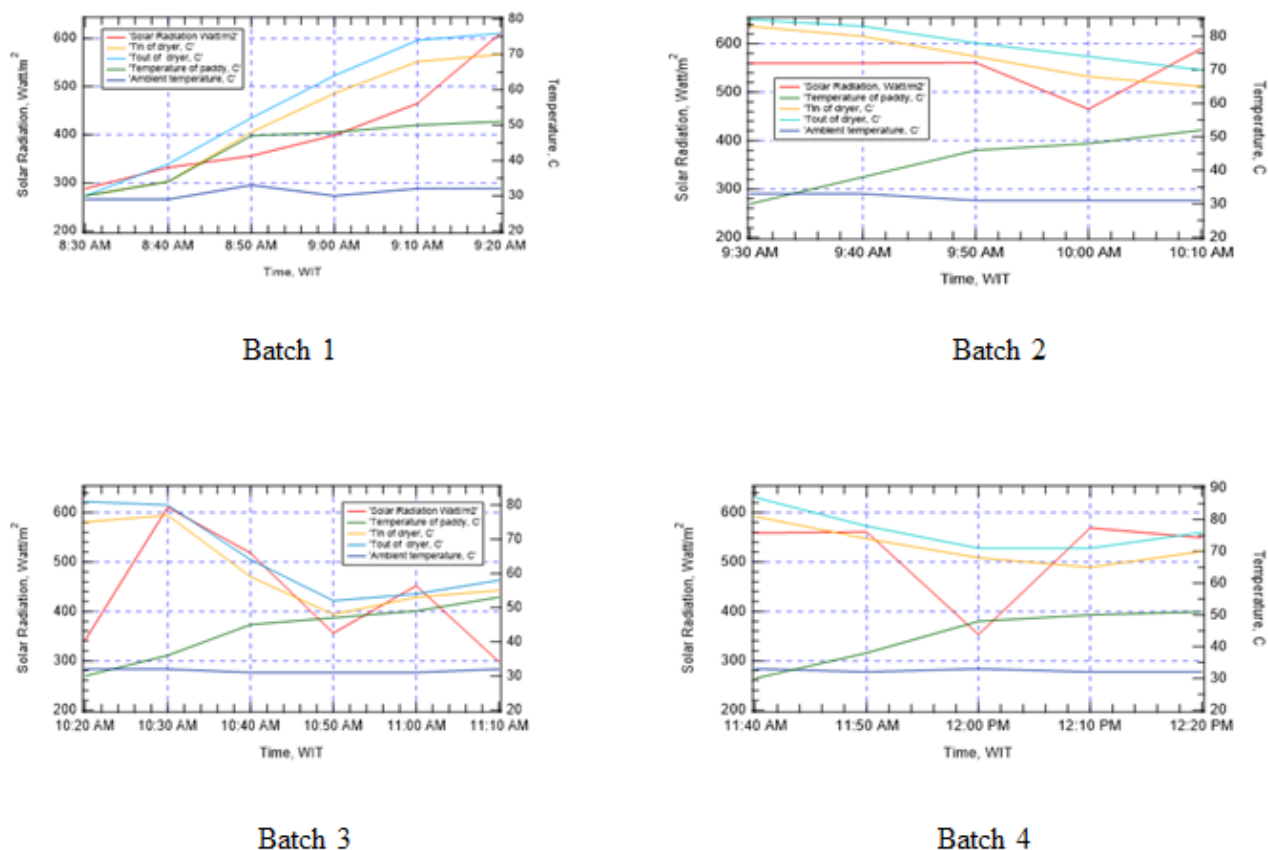


Fig 4. Effect of solar radiation on drying time and temperature

Theoretically, a parabolic type collector is able to convert radiation into a form of thermal energy reaching 250°C⁽¹³⁾ and this is highly dependent on the type/reflector material that coated the collector’s surface. The higher the reflectivity value of the material, the more incoming light is reflected in the focal point (dryer). However, paddy drying only requires low temperature, so the aluminum sticker material that is widely available on the market with a relatively inexpensive paddy is already meeting the material selection criteria.

Of the four tests carried out, the drying time of batch 2 and batch 4 is the shortest, which is 40 minutes, while batch 1 and batch 3 are 50 minutes. Based on these four profiles, it appears that when the average radiation intensity is less than 500 Watt/m², the drying time will be more than 40 minutes.

Of the overall drying is carried out, the temperature of paddy is in the average range of 43 - 45°C. Thus, this temperature still meets the drying conditions recommended⁽³⁾ so that the quality of paddy is maintained.

3.2 Drying performance

The performance of this solar-based paddy dryer is measured by calculating efficiency, SEC, SMER, and drying rate. The results are explained as follows:

a. Drying efficiency

From the results of the calculation of the efficiency of paddy drying carried out on 4 batches of drying time and temperature can be seen in Figure 5, where the incoming energy (available) includes the energy supplied by the parabolic collector and the energy to move the conveyor as described in equation 1) Used energy is calculated using equation 2) By using the average paddy heat capacity value of 1.6919 kJ / kg.°C⁽¹⁴⁾, the water heat capacity is 4.2 kJ / kg.°C, the calculation results are obtained as presented in Figure 5.

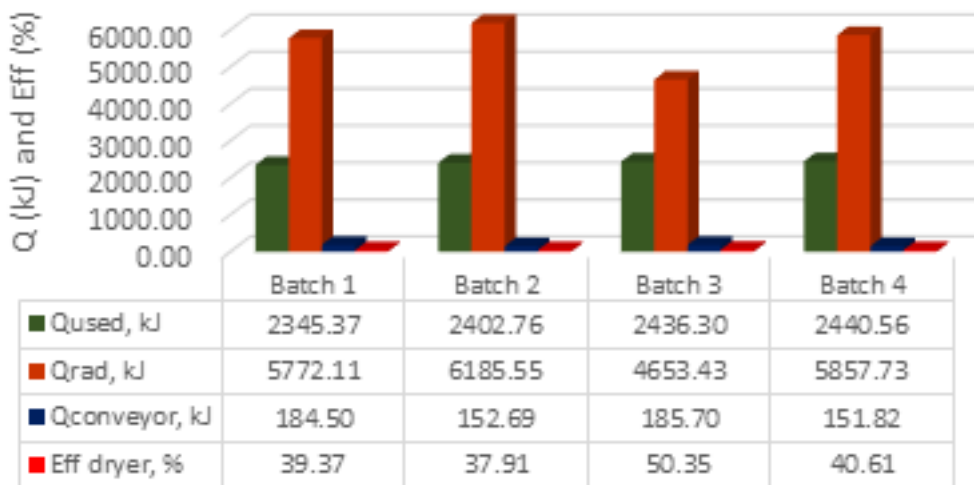


Fig 5. Dryer efficiency at every batch

Overall thermal efficiency of drying is in the range 37.91 - 50.35%. The highest thermal efficiency is achieved in batch-3 drying. This is because efficiency is the ratio between energy used for evaporation vs. energy received (radiation energy and energy to move the conveyor). With relatively higher used energy than in batches 1,2 and 4, while the lowest average radiation results in thermal efficiency being greater.

b. SEC, SMER, and drying rate

The calculated results of specific energy consumption values expressed as SEC values indicate that the four batch drying processes show values in the range of 5,318 - 7,042 MJ/kg H₂O evaporated. This value indicates that drying using a parabolic cylinder type solar dryer is more effective than that done by foreign researchers. Paddy drying using Industrial Inclined Bed Dryer (IBD): 5.45 - 8.24 MJ/kg H₂O evaporated⁽¹⁵⁾. Whereas paddy-drying using the Industrial Horizontal Rotary Dryer (IHRD) consumes: around 10.43 MJ/kg H₂O evaporated⁽⁶⁾.

Of the four batch processes, batch-4 has the most optimum performance (according to Fig 4), where the solar irradiation is at its peak level, whereas other batches have not reached the optimum condition. Batch-4 shows the highest drying rate, 40 minutes drying time, and relatively low specific energy consumption of 6.532 MJ/kg H₂O evaporated. In addition, the performance (seen from the SEC value) of the solar thermal paddy dryer using a designed parabolic collector is better than the results of foreign researchers⁽⁶⁾.

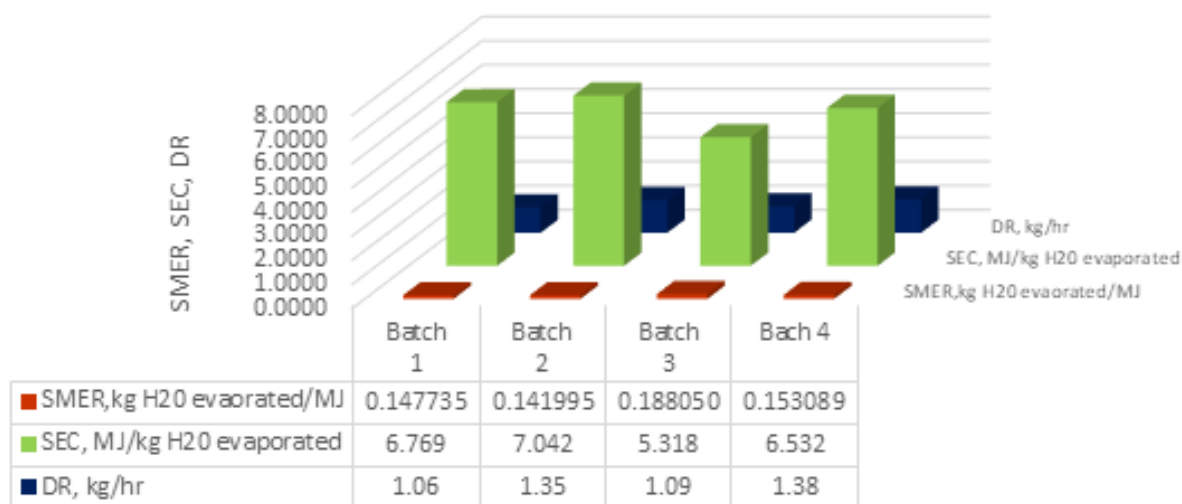


Fig 6. SEC, SMER and DR of paddy drying using solar parabolic dryer

4 Conclusion

Paddy drying from the moisture content of 28% to 14% (w.b) using a parabolic cylinder type solar dryer equipped with a screw conveyor at a speed of 23 rpm has been carried out. From the variation of drying time which took place in 4 (four) batches starting from batch 1 (08:30 - 09:20), batch 2 (09:30 - 10:10), batch 3 (10:20 - 11:10) and batch 4 (11:40 - 12:20) WIT, with a capacity of 5 kg of paddy/batch indicating that the intensity of solar radiation is in the range of 408.5 - 547.2 Watt/m². The highest radiation intensity takes place in batch 2 with the maximum temperature in the dryer reaching 74°C. Overall the experiments carried out obtained the condition of the temperature of paddy during drying in the average range of 43 - 45°C, with the shortest drying time achieved in batches 2 and batch 4 i.e. 40 minutes.

The performance test results show the thermal efficiency of the dryer is in the range of 37.91% - 50.35%, specific energy consumption of 5.318 - 7.042 MJ/kg H₂O evaporated, with a drying rate of 1.06 - 1.38 kg/day. Optimal drying conditions are achieved in batch 4 (11:40 - 12:20 WIT) where the shortest drying time is 40 minutes with a thermal efficiency of 40.61%, SEC 6.652 MJ/kg H₂O evaporated and a drying rate of 1.38 kg/day.

References

- 1) Pusat SB. Luas Panen dan Produksi Padi di Indonesia 2019 Hasil Survei Kerangka Sampel Area (KSA), Berita Resmi Statistik No. 16/02/Th. XXIII, 4 Februari 2020. .
- 2) Sookramoon K. Design of a Solar Tunnel Dryer Combined Heat with a Parabolic Trough for Paddy Drying. *Applied Mechanics and Materials*. 2016;851:239–243. Available from: <https://dx.doi.org/10.4028/www.scientific.net/amm.851.239>.
- 3) Zheng X, Lan Y. Effects of Drying Temperature and Moisture Content on Rice Taste Quality. *Agricultural Engineering International: the CIGR Ejournal Manuscript FP07 023*. 2007;9.
- 4) Mehdizadeh Z, Zomorodian A. A Study of the Effect of Solar Drying System on Rice Quality. *Journal Agricultural Science and Technology*. 2009;11:527–534.
- 5) Gazor HR, Alizadeh MR. Comparison of rotary dryer with conventional fixed bed dryer for paddy drying, milling quality and energy consumption. *Agriculture Engineering International: CIGR Journal*. 2020;22(2):264–271.
- 6) Firouzi S, Alizadeh MR, Haghtalab D. Energy consumption and rice milling quality upon drying paddy with a newly-designed horizontal rotary dryer. *Energy*. 2017;119:629–636. Available from: <https://dx.doi.org/10.1016/j.energy.2016.11.026>.
- 7) Udomkun P, Romuli S, Schock S, Mahayothee B, Sartas M, Wossen T, et al. Review of solar dryers for agricultural products in Asia and Africa: An innovation landscape approach. *Journal of Environmental Management*. 2020;268. Available from: <https://dx.doi.org/10.1016/j.jenvman.2020.110730>.
- 8) Salvatierra-Rojas A, Nagle M, Gummert M, Bruin TD, Muller J. Development of an inflatable solar dryer for improved postharvest handling of paddy rice in humid climates. *International Journal Agriculture & Biology Engineering*. 2017;10(3):269–282. Available from: <https://doi.org/10.3965/j.ijabe.20171003.2444>.
- 9) Gazor HR, Alizadeh MR. Comparison of rotary dryer with conventional fixed bed dryer for paddy drying, milling quality and energy consumption. *Agriculture Engineering International: CIGR Journal*. 2020;22(2):264–271.
- 10) and Rufai YA YI. Design, Construction and Testing of Parabolic Solar Oven. *Journal of Applied Mechanical Engineering*. 2016;5(4). Available from: <https://dx.doi.org/10.4172/2168-9873.1000212>.
- 11) Craig OO, Dobson RT, van Niekerk W. A Novel Indirect Parabolic Solar Cooker. *J of Electrical Engineering*. 2017;5(3):2168–9873. Available from: <https://dx.doi.org/10.17265/2328-2223/2017.03.003>.
- 12) Dina SF, Ilmi A, Masriani RS, Putra MS. Design of Parabolic Solar Cooker: As Alternative Cooker Trough Go Green In Medan. *Indonesia, Indian Journal of Science and Technology*. 2019;12(10). Available from: <https://doi.org/10.17485/ijst/2019/v12i10/142206>.
- 13) Ghassemi A. Solar Energy – Renewable Energy and the Environment. and others, editor;CRC Press. 2009.
- 14) Iguaz A, Martin MBS, Arroqui C, Fernandez T, Mate JI, Virseda P. Thermophysical properties of medium grain rough rice (LIDO cultivar) at medium and low temperatures. *European Food Research and Technology*. 2003;217(3):224–229. Available from: <https://dx.doi.org/10.1007/s00217-003-0760-x>.
- 15) Sarker MSH, Ibrahim MN, Aziz NA, Punan MS. Drying Kinetics, Energy Consumption, and Quality of Paddy (MAR-219) during Drying by the Industrial Inclined Bed Dryer with or without the Fluidized Bed Dryer. *Drying Technology*. 2013;31(3):286–294. Available from: <https://dx.doi.org/10.1080/07373937.2012.728270>.