Solar Dryer

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Abstract

By 2040, the National Energy Policy and the Malaysian Renewable Energy Roadmap have set goals to lower the amount of coal in generating capacity to 18.6% and raise the share of renewable energy to 40%. To advocate this, we suggest solar dryers that make use of the sun's energy, a plentiful and sustainable energy source that is constantly available and doesn't diminish as it is utilised. Utilising solar energy decreases the need for non-renewable energy sources, such as fossil fuels, which lowers the carbon footprint and minimises reliance on finite resources. Our solar dryer intends to increase access to inexpensive, dependable, and sustainable energy in line with Sustainable Development Goal 7 of the 2030 Agenda through its transparent, constant, and reliable performance. Our invention stands out not just for its original mechanism but also for the way it makes use of recyclable materials. Traditional drying techniques have several negative environmental effects, which solar drying helps to mitigate. For instance, biomass fire is frequently used to dry agricultural products in many developing nations, which causes deforestation, indoor air pollution, and health risks. With the use of solar dryers, these methods are no longer necessary, resulting in better air quality, less deforestation, and a healthier ecosystem.

Keywords: *background, problem statement, description innovation, objective, novelty, societal benefits*

1.0 Introduction

Recent years have seen a significant increase in the importance of solar energy-based systems for supplying clean energy and avoiding the adverse environmental impacts of existing fossil fuel-based systems. Countries use renewable energy because of the growing global population and a corresponding rise in energy consumption. Energy is a critical resource for technology, evolution, and social growth, as global energy consumption rises year after year and the global economy expands rapidly. Furthermore, a rising global population means rising demand for electricity, space heating and cooling, food, and consumer goods .Global electricity consumption has steadily increased at an annual rate of 3% over the last ten years. The current trend is expected to continue in the coming years. By 2050, the global population will have surpassed 9 billion, implying a 70% increase in food production and a corresponding increase in energy demand.

Massive energy consumption has put an enormous strain on energy resources and resulted in serious environmental issues. Reduced energy consumption is critical due to the negative impact on the environment and the finite nature of fossil fuels. This could be accomplished through process optimization and technological changes as part of an energy efficiency strategy. Long-term initiatives include decarbonization and a shift toward cleaner, more environmentally friendly renewable energy sources such as solar, biomass, hydropower, and wind. The benefits of renewable energy have been widely discussed in the public domain. Solar energy has piqued the interest of many researchers and developers due to its abundant supply and low capital investment, particularly for basic and home applications. The sun provides solar energy. It has been proven to be clean and safe for use, with no negative impact on the environment or society. The total annual solar radiation received by Earth exceeds 7500 times the total annual primary energy consumption of the world, which is 450 EJ. The abundant supply of solar energy, particularly in tropical countries, creates a huge potential for its use in the domestic and industrial sectors. Since then, there have been numerous studies and developments in solar energy to better suit its application in the modern world.

A clean, affordable, and sustainable energy source, solar energy can be used for a variety of tasks, including drying. Implementing solar radiation allows one to produce both electrical and thermal energy. One of the most traditional and widely used methods for preserving food and agricultural goods is drying. Drying has been used to preserve agricultural, marine, and herbal products for many years. It has a number of benefits, including preserving the product's flavour, nutrients, and quality, improving appearance, extending shelf life for consumer use, and reducing packaging and shipping capacity. The removal of moisture through the drying process also prevents mould and bacteria from growing and spoiling the food. Aside from the agricultural sector, the drying process is also widely used in the timber industry, where wood planks are dried to remove moisture before further processing. Wood drying techniques used in wood processing include air-drying and kiln-drying. Drying is an important process in the manufacturing of food, chemicals, textiles, cement, and pharmaceutical products in the industrial sector. Conserving drying products through the use of solar energy drying systems is a practical and affordable solution.

1.3 Problem Statement

The challenge we face is to conceive a versatile, economically accessible, and environmentally conscious solar-powered dryer that addresses the escalating demand for sustainable and efficient drying solutions in diverse industrial and application contexts. This innovative dryer should harness solar energy efficiently, ensuring dependable and eco-friendly drying processes that are within financial reach for users in both developed and developing regions. This endeavour necessitates careful consideration of affordability, energy efficiency, adaptability, and environmental impact, as these factors collectively underpin our commitment to meeting the burgeoning need for sustainable drying solutions worldwide.

1.2 Objective

Our solar dryer intends to increase access to inexpensive, dependable, and sustainable energy in line with Sustainable Development Goal 7 of the 2030 Agenda through its transparent, constant, and reliable performance

2.0 Literature Review

2.1. Box-type (Cabinet) Natural Convection Solar Dryer

Amin Omda Mohamed Akoy et al. observed the design and construction of a box-type (cabinet) natural convection solar dryer. The dryer was built with a drying chamber and a solar collector combined into one unit, as shown in Figure 1. They concluded that the designed dryer, with a solar collector area of 16.8 m2, is expected to dry 195.2 kg fresh mango (100kg sliced mango) from initial moisture 81.4% to 10% final moisture in two days under ambient conditions from April to June. A dryer prototype with a 1.03m2 solar collector area was built to be used in experimental drying tests. The average ambient conditions are 30°C air temperature, 15% relative humidity, and an air flow rate of 0.0903 kg/s, with a daily global solar radiation incident on the horizontal surface of approximately 232 W/m2 for a drying time of 10 hours per day.

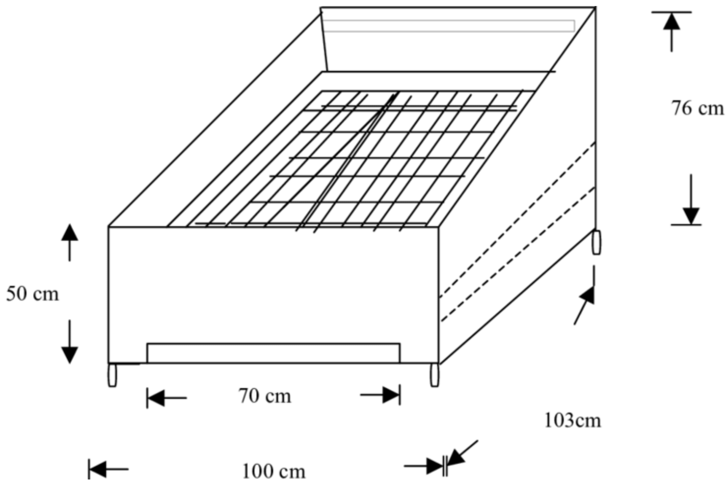

Figure 1. Isometric view of constructed solar dryer

2.2. Mixed Mode Type Forced Convection Solar Tunnel Dryer

M.A. Hossaina and B.K. Bala used a mixed mode type forced convection solar tunnel dryer to dry hot red and green chillies in Bangladesh's tropical weather conditions, as shown in Figure 2 consists (of 1. air inlet 2. Fan 3.solar module;4.solar collector;5.side metal frame;6.outlet of the Collector 7.wooden support; 8.plastic net; 9.roof structure for supporting the plastic cover; 10.base structure for supporting The dryer;11.rolling bar; 12,outlet of the drying tunnel.) The drier could hold 80 kg of fresh chilies. The moisture content of red chilli was reduced from 2.85 to 0.05 kg/kg (db) in 20 hours in a solar tunnel dryer and to 0.09 and 0.40 kg/kg (db) in 32 hours in improved and conventional sun drying methods, respectively. In the case of green chilli, a moisture content of about 0.06 kg/kg(db) was obtained from an initial moisture content of 7.6 kg/kg(db) in 22 hours in a solar tunnel dryer. The average air temperature rise in the dryer was approximately 21.62 ºC

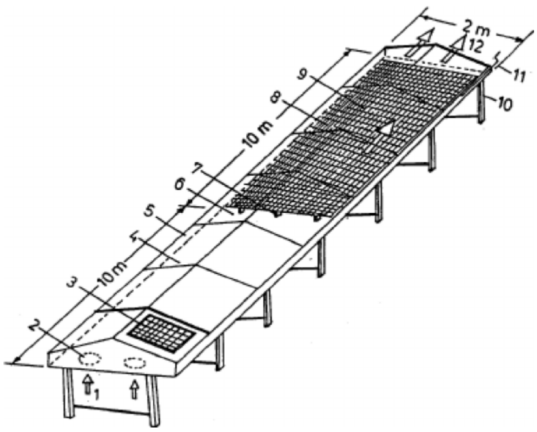

Figure 2. Mixed mode type forced convection solar tunnel dryer

3.0 Methodology

3.1 Materials

Table 1. List of Materials

Material Name	Material Amount
Aluminium sheet 0.4m x 0.61m	1
Aluminium Cans 11.5cm x 6.6cm	24
Heat Resistant Metal Glue 100g	10
UPVC Elbow Pipe 2"	6
UPVC Pipe 3ft 2"	1
Wooden Plank 3ft x 4" x 17mm	11
Glass pane 60cmx40cmx2mm	11
Photovoltaic Cell	3
Fan	1
Black Paint 1L	1
Glass pane 60cmx40cmx2mm	1
StainlessSteel Bearing Hinge	2
Wire Mesh	2

3.2 Design

Solar Air Collector

A cheap solar air collector was built with empty aluminium cans and an aluminium plate as the absorber surface. Aluminium cans are glued together to form four air channels with a length of 69cm each and an internal diameter of 6.6 cm as shown in figure 3. These four air channels are connected forming a 276cm continuous air passage. An absorbing plate made of an aluminium sheet with 1 mm in thickness was placed under the channels. They are then fixed inside a tight box to prevent heat leakage. All parts are painted with opaque dark paints to increase the heat absorptivity of the collector (Absorptivity ≈ 0.95–0.97). Finally, the collector was covered with a 3mm transparent glass plate to reduce convective losses to the atmosphere. Solar radiation passes through a transparent glass plate and hits the absorber surface which heats up and transfers the heat to the air inside the channels.

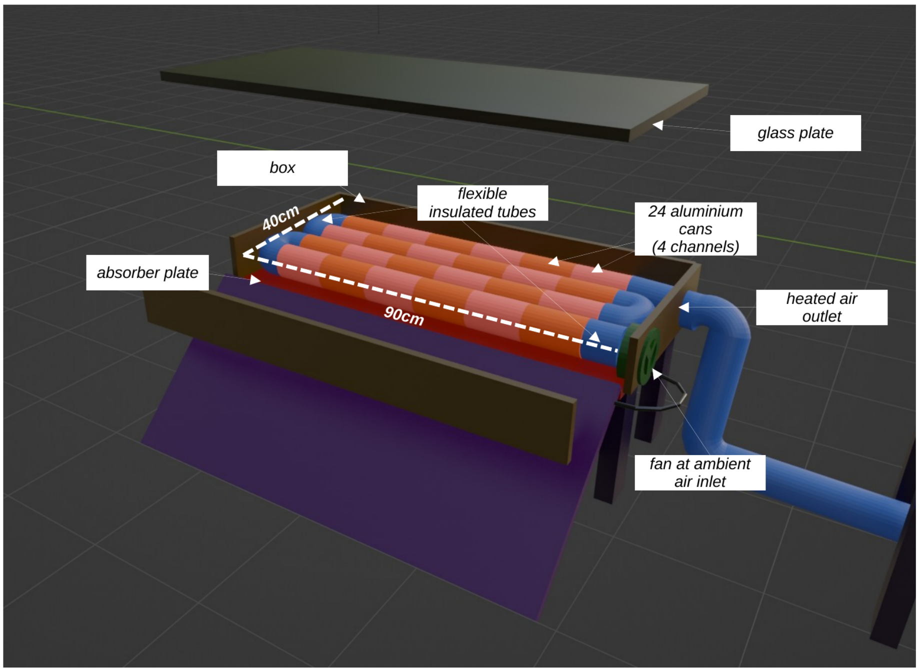

Figure 3. Schematic assembly of the designed solar collector.

Drying Cabinet

A wooden drying cabinet with a size of 40 cm Length × 33.5 cm Width × 60 cm Height was constructed from wood as shown in Fig. 4. The cabinet has two trays to put the products on. The cabinet has one circular hole (drying air inlet) at the bottom and one circular hole at the top (drying air inlet). These circular holes are 5.20 cm in diameter. To ensure the equal distribution of the air inside the cabinet, a wooden plate with many circular holes is placed above the inlet hole. The heated air in the collector is forced through the air channels towards the inlet hole of the drying cabinet and exits through the outlet hole.

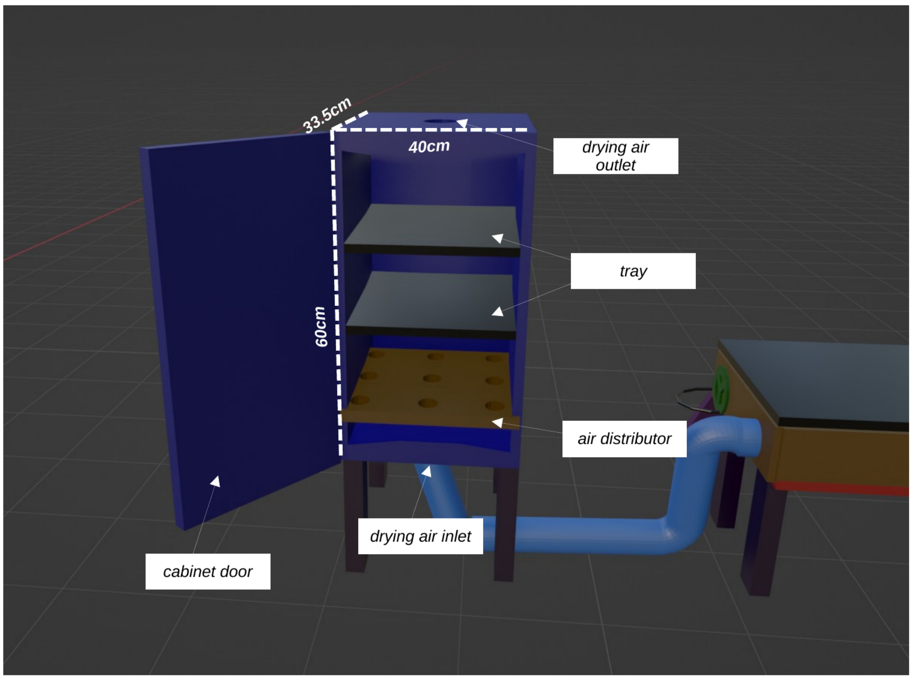

Figure 4. Drying cabinet with trays.

4.0 Results

4.1 Cost Estimation

Approximate estimation of the average cost for constructing a low-cost solar air heater is given in Table 2 and Table 3. The overall cost and choice of materials would promote mass production and hence, it can be a substitute for the expensive conventional dryers thereby making it accessible and affordable for local farmers.

Table 2. Cost Estimation for Heat Collector

Heat Collector

Material Name	Material Amount	Cost per unit (RM)	Material Cost (RM)
Aluminium sheet 0.4m x 0.61m	1	35	35
Aluminium Cans 11.5cm x 6.6cm	24	0.08	1.92
Heat Resistant Metal Glue 100g	10	7.2	72
UPVC Elbow Pipe 2"	6	1.5	9
UPVC Pipe 3ft 2"	1	6.5	6.5
Wooden Plank 3ft x 4" x 17mm	2	7	14
Glass pane 60cmx40cmx2mm	11	5.6	5.6
Photovoltaic Cell	3	29	87
Fan	1	26	23
Black Paint 1L	1	23	26
Total Cost			280.02

Table 3. Cost Estimation for Drying Chamber

Drying Chamber

Material Name	Material Amount	Cost per unit (RM)	Material Cost (RM)
Stainless Steel Bearing Hinge	2	4.5	9
Wooden Plank 3ft x 4" x 17mm	9	4	36
Wire Mesh	2	1.1	47.2
Total Cost			92.02

4.2 Economic Analysis

To assess the economic impact, we performed some calculations. First, we considered the fixed costs of the acquisition of the electric dryer and the components needed for the construction of the prototypes. Then we considered the running costs of the electricity for the electric dryer.
The electric commercial dryer had an acquisition cost of RM300 and had a capacity of around 1.5 kg/batch. We considered a reintegration time of 5 years with 60 runs per year. For our model, all components and raw materials (wood, fans, net, tray sliders, glass, paint, and glue) had a cost of around RM327.22 and had a capacity of 2 kg/batch. We considered a utilisation time of 4 years with 50 runs/year.

On average, a dehydrator uses around 5 kilowatt-hours per session, based on the average dehydrator wattage of 500 watts, and an average session of ten hours. Per month, assuming that food is dried using the dehydrator for one session a week, then the average electricity consumption of the dehydrator would be around 20 kWh per month. In Malaysia, the official conversion values for domestic users are 0.18 €/kWh and 622 gCO2e/kWh , which means a cost of RM3.60 and an emission of 12.44 kg of CO_2 per month.

Although the overall cost is higher, the average capacity of our model is higher. Other than that, both electricity consumption cost and electricity consumption carbon dioxide emission can be avoided because the model runs on solar energy.

4.3 Drying System

The drying mode that is used here is an ‘open’ drying system that is commonly used for all drying scenarios of most agricultural products. The fresh dry air enters the drying system through the air inlet, and it is heated in the collector. It is then forced to the drying cabinet to heat the products in the cabinet. Finally, the air leaves the system completely through the air outlet. A fan is used to pump the air into the solar collector. The fan is operated using a photovoltaic panel. Polyethylene flexible tubes (with 5.08 cm in diameter) insulated by thermal wool (2 cm in thickness) were used to convey the air from solar collectors to the drying cabinets. The performance of the solar dryer was compared with that of the traditional ambient sun drying.

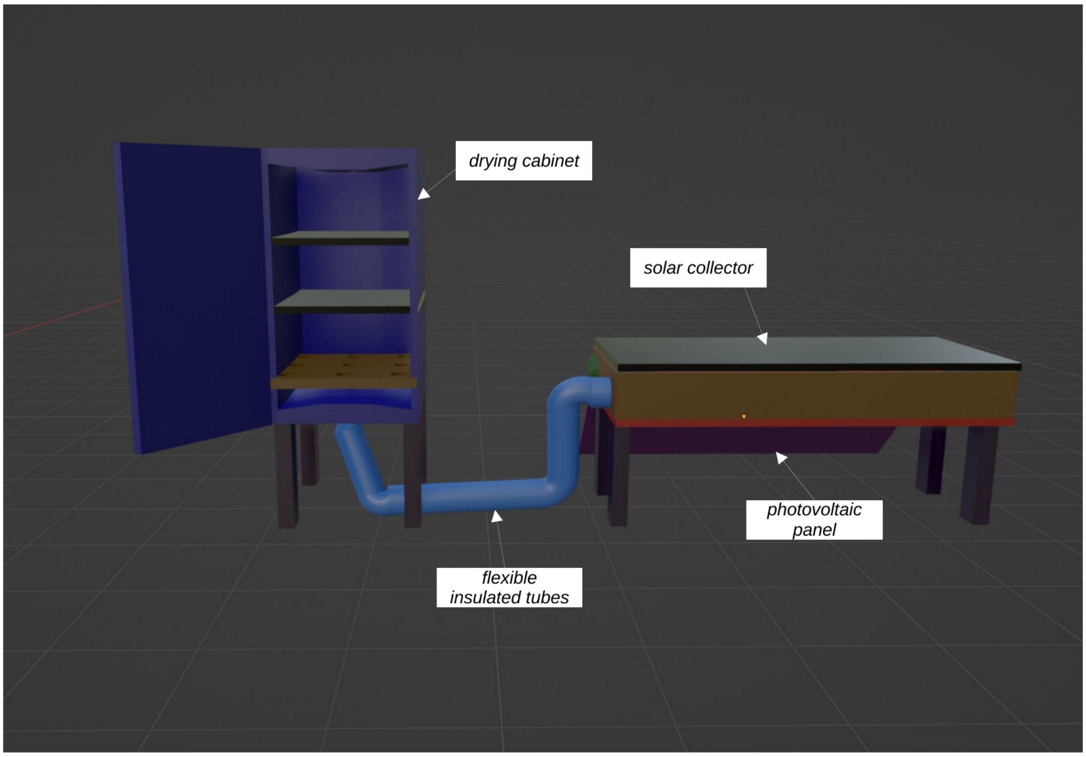

Figure 5. solar air collectors integrated with drying cabinets.

5.0 Conclusion

The diverse changes that society has endured have led to the transformation of forms of production and consumption. Environmental issues have taken centre stage in scientific debates because they have become threats to the quality of life on the planet because of human actions.
Several solar dehydrator designs are available in the market and some of these require expensive materials, which makes them difficult to obtain for small producers. Solar dryers are generally low-cost because they are made of locally available materials with simple construction. In addition, the energy required to dry food is less than needed to freeze or canned food, which mitigates the consumption of conventional sources of energy, allowing the reduction of CO_2 emissions.

An efficient and economical solar dryer for drying vegetables and fruits was designed and developed. The results showed that the use of recyclable aluminium cans in manufacturing air solar collectors is technically and economically feasible if an adequate design is applied and optimum operating parameters are implemented. As this technique needs a low initial cost to construct, less effort to exert and less labour to employ, it is more beneficial to small-scale farmers who cannot afford fuel-operated drying systems. The association with aluminium cans and other recycled materials makes the process more costly and environmentally friendly, avoiding improper disposal of waste. Despite their many advantages, solar dryers have some limitations that influence their performance and negatively affect the drying rate, specifically, the fact that their use is exclusively limited to the daytime period and only if there is sufficient solar radiation.

The use of solar drying for agricultural products has a large potential from a technical and energy-saving point of view. Dehydration is a key technology to preserve fresh fruits in rural areas and thereby reduce food waste. Considering the low-income level of the rural population in developing countries, the high initial costs of solar drying systems represent a great challenge for their usage. However, manufacturing these systems from recyclable and affordable materials is very beneficial for farmers to adopt given the better quality product and less product waste. The solar dryer can reduce production costs, energy consumption, and waste (using fruits outside the quality standard for fresh consumption) and is an alternative for small and medium producers.

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7.0 References

Council of the European Union. (2016, December 6). *Odour nuisance - Information from the Polish delegation*. https://data.consilium.europa.eu/doc/document/ST-15267-2016-INIT/en/pdf

da Silva, O. B., Carvalho, L. S., de Almeida, G. C., de Oliveira, J. D., Carmo, T. S., & Parachin, N. S. (2017, February 8). *Biogas - Turning Waste into Clean Energy*. IntechOpen. https://doi.org/10.5772/64262

Iacovidou, E., & Siew, K. (2020, July 29). *Malaysia Versus Waste*. Brunel University London. https://www.brunel.ac.uk/news-and-events/news/articles/Malaysia-Versus-Waste

Kishk, S. S., ElGamal, R. A., & ElMasry, G. M. (2019). Effectiveness of recyclable aluminum cans in fabricating an efficient solar collector for drying agricultural products. *Renewable Energy*, *133*, 307–316. https://doi.org/10.1016/j.renene.2018.10.028

Oztop, H.F.; Bayrak, F.; Hepbasli, A. Energetic and exergetic aspects of solar air heating (solar collector) systems. Renew. Sustain. Energy Rev. **2013**, 21, 59–83.

Sámano Delgado, E.; Martinez-Flores, H.; Garnica-Romo, M.; Aranda-Sanchez, J.; Sosa-Aguirre, C.; De Jesús Cortés-Penagos, C.; Fernández-Muñoz, J. Optimization of solar dryer for the dehydration of fruits and vegetables. J. Food Process. Preserv. **2013**, 37, 489–495.

Tiwari, A. A Review on Solar Drying of Agricultural Produce. J. Food Process. Technol. **2016**, 7, 1–12.

Voulvoulis, N.; Burgman, M.A. The contrasting roles of science and technology in environmental challenges. Crit. Rev. Environ. Sci. Technol. **2019**, 49, 1079–1106.