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# Review on Technique used in Solar Dryer

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## Abstract

*This paper presents an overview of solar dryer technologies, highlighting current concerns, offering potential research directions, and gathering the most recent advancements. A sustainable and environmentally beneficial way to preserve food products, agricultural produce, and other commodities is solar drying. The review starts off by explaining the basic ideas behind solar drying procedures, including different design setups and operating parameters. The performance of various solar dryer types- direct, indirect, and hybrid systems- is methodically assessed in this paper, with a focus on each system's benefits and drawbacks. Indirect natural convection solar drying technique was used to dry banana slices with drying efficiency of 22.38%. Also, v shape corrugations were used on absorber plate to further improve the drying efficiency. It also covers new developments in design elements and materials that improve the dependability and efficiency of solar dryers. Absorber plates were coated with black paint containing 1% graphene nanomaterial. Impact of thickness of glass cover on drying efficiency was studied. Parabolic concentrators are used to enhance the efficiency of solar dryers. The drying time was reduced by 21% compared with solar dryers without concentrator. Additionally, the review covers important factors like affordability, scalability, and adaptability to various applications and climates.*

***Major Findings:*** *The performance of various solar dryers has been studied in this paper. It has been found that drying efficiency can be improved by providing black paint coating containing 1% graphene nanomaterial. Parabolic concentrators have a significant impact on the performance of solar dryers.*

**Keywords:** *Dryer Setups, Solar Dryers, Solar Energy and Concentrators*

## 1.0 Introduction

From last so many years, solar energy is being used for drying and preserving agricultural and horticultural products, the immense prospects of solar energy in the food processing industries is not well explored scientifically. By utilizing the sun's plentiful and renewable energy, solar dryers offer a sustainable substitute for traditional drying techniques that depend on non-renewable energy sources. This helps to make the drying process more ecologically and energy-efficient while also lowering reliance on fossil fuels. In areas with plenty of sunlight, solar drying can drastically lower the operating costs related to conventional drying techniques. Businesses and farmers can reduce their energy costs and increase the economic viability of the drying process by utilizing free solar energy.

Solar dryers provide a mild and regulated drying atmosphere that aids in maintaining the nutritional value of food itemsand agricultural produce. Maintaining the quality and market value of dried goods is contingent upon this. Solar dryers play a pivotal role in reducing post-harvest losses by preventing spoilage and degradation of perishable goods. Farmers can extend the shelf life of crops and minimize waste, leading to increased profitability and improved food security.

Moreover, solar dryers can empower rural communities by giving them a dependable and affordable

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way to process and preserve their agricultural produce in many areas, especially in developing nations[1]. This enhances livelihoods and promotes local economic growth. They are particularly useful in isolated or off-grid locations with limited access to electricity are solar dryers. Decentralized drying solutions can be implemented in areas lacking a stable power infrastructure due to their solar- powered nature and ease of use. Conventional drying methods make use of air dryers, which burn a significant amount of fossil fuel. However, the rising cost of fossil fuels, their depletion, and growing environmental concerns emphasize the need to use renewable energy sources like solar energy as a backup energy source in both underdeveloped and developing nations.

The benefits of using a solar drying system include: (i) dried products under an open sun drying system have a dark brown color, whereas in a solar air-drying system, the products retain their natural color; (ii) the products' physical characteristics, such as their hardness and smell, were satisfactory in comparison to an open sun drying system. (iii) Products dried in solar dryers are shielded from rain, insects, and dust; additionally, the dried products have excellent flavor, color, and texture (iv) The product's moisture content can be adjusted to meet specific requirements; and (v) uniform drying of the product can be achieved through appropriate air heater and dryer design. Using solar energy to dry agricultural products—and medicinal plants in particular—has grown to be one of the most well-liked and alluring financial ventures[2].

## 2.0 Classification of Solar Dryer

### 2.1 Direct Solar Dryers

Through a transparent material covering the structure, the product to be dried is exposed directly to solar radiation. In addition to warming the surrounding area, the heat produced by solar radiation is utilized to dry crops and food products. The primary drawback of utilizing the direct mode is the inability to regulate the amount of heat that the object will absorb. The heat-absorbing plate of this type of solar dryer is painted black and has the ability to collect, absorb, and convert sunlight into heat. The product that needs to be dried is immediately placed on top of the absorbing plate. To increase thermal efficiency, this dryer could have glass lid covers and vents.

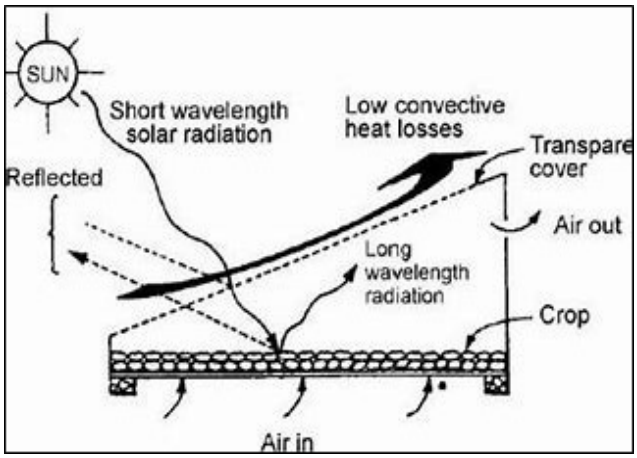



**Figure 1.** Direct solar dryer[3].

### 2.2 Indirect Solar Dryers

The two primary components of the indirect solar dryer[4] are the drying cabinet, which keeps materials on trays, and the solar collector setup, which consists of an absorber plate and a glass plate. After that, the product is heated, and the moisture is removed by blowing hot air over the food to be dried. The product is held in place while it dries in the drying chamber by wire mesh trays. The solar collector setup is made up of a glass cover and absorber plate that are attached to the drying chamber at a specific angle that varies based on the latitude of the location. Black paint is applied to the absorber specifically to maximize its ability to absorb solar radiation. As solar radiation hits a glass cover, it undergoes a variety of heat transfer processes. Some of the radiation is reflected back into the surrounding air, while other portions are transmitted through the cover, from the cover to the atmosphere (transmission loss), absorbed by the absorber plate, and transferred by convection to heat the air that enters the chamber.

### 2.3 Mixed-Mode Solar Dryers

Passive and active solar drying modes are combined in mixed-mode solar dryers, a type of solar drying system. To improve drying efficiency, these dryers combine the principles of solar radiation, mechanical airflow, and

natural convection. The term "mixed mode" refers to the twofold character of the drying processes that are at play-direct and indirect drying.

### 2.4 Hybrid Solar Dryers

The hybrid solar dryer is the next step forward from the active solar dryer. To achieve appropriate drying conditions, a hybrid solar dryer can use many sources of energy in addition to solar energy. The incoming air may occasionally be preheated using biomass energy, electrical energy, heat exchange, or desiccant to boost the dryer's internal heat transfer rate. While hybrid dryers can operate in both passive and active modes of heat transmission, the active mode is more typically used. A solar photovoltaic panel powers an exhaust fan when the solar dryer is in its active mode. Although grid-connected electricity is another option, solar photovoltaic panels are typically utilized in practice.

## 3.0 Solar Drying Technologies

Lingayat A, Chandramohan VP, Raju VRK were able to develop an indirect natural convection solar dryer for drying banana slices[5]. The collector, made from galvanized iron and was tilted at an angle of 23.5 degrees. It had the dimensions 0.4 m × 1 m (width, depth, and height). The absorber plate was made of copper and had an area of 2m$^2$. It also had V-shaped corrugations. Rock

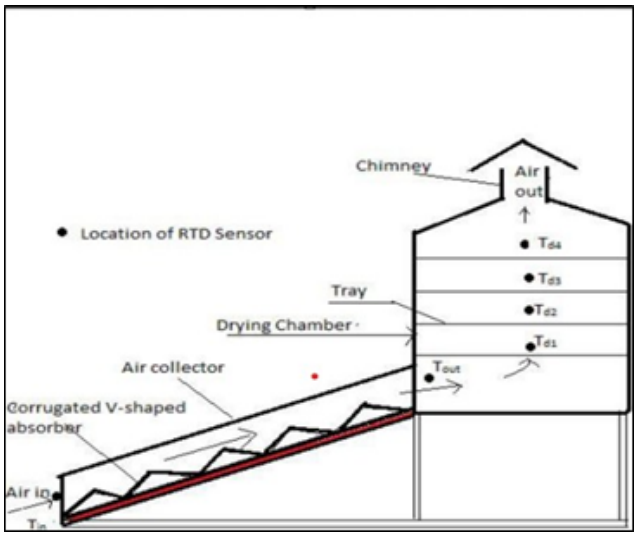



**Figure 2.** Experimental setup for drying of banana slices[5].

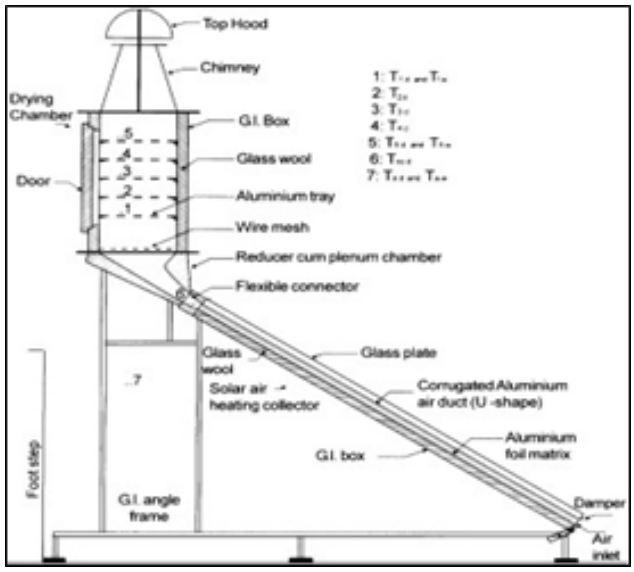



**Figure 3.** Experimental setup for drying of grapes[6].

wool was used for insulation. Four aluminum trays (0.9 m×0.4 m) were vertically placed 0.011m apart from each other.

The mass of the bananas decreased from 2 kg to 0.5628 kg. Banana moisture content decreased for Tray1, Tray2, Tray3, Tray4, and open sun drying, from an average initial value of 356 (db) to final values of 16.3292 percent, 19.4736 percent, 21.1592 percent, 31.1582 percent, and 42.3748 percent (db), respectively. The drying efficiency was 22.38 percent, and the collector's average thermal efficiency was 31.50 percent. In addition to cutting down on drying time, the solar dryer produced a better-quality product than open-air sun drying, making it more effective.

Pangavhane DR, Sawhney RL, Sarsavadia PN in their paper, "Design, development and performance testing of a new natural convection solar dryer", came up with a solar dryer which had V-shaped corrugations on the collector plate[6]. The plate itself was made of aluminum and it had 11 U- shaped corrugations parallel to the direction of airflow. It also had aluminum fins on the back side. The primary construction materials were galvanized iron and aluminum. Glass wool was used for insulation. The dimensions of the drying chamber were 0.35m × 0.35m × 0.70m. This dryer featured flexible tilt which allowed for maximum radiation absorption at all times. Thompson seedless grapes (*Vitis vinifera*) were used for testing the working of the dryer.

Five aluminum trays, each holding the product, were arranged equally and spaced 0.09m apart vertically in the drying chamber. RTD Pt-100 sensors (accuracy±0.1°C) were installed at the solar air collector outlet (Tco, d) and each tray in the drying cabinet (T1;d, T2;d, T3;d, T4;d, T5;d) to monitor dry bulb temperature. To detect wet bulb temperatures in these places, RTD Pt-100 sensors with wet wicks were installed in the drying chamber's first (T1,w) and fifth (T5,w) trays.

Every hour, the sample was weighed in order to calculate the percentage of moisture content reduction. With the input air temperature of 38°C, the maximum air temperature at the dryer inlet under no load conditions was measured to be 69.5°C. Grapes and the majority of other fruits and vegetables may be dried at an optimal temperature of between 50 and 55°C, which is the average that the created natural convection sun drier can generate. The collector efficiencies of this natural convection solar dryer ranged from 0.26 for 0.0126 kg/s to 0.65 for 0.0246 kg/s, which were sufficient for heating the drying air. Furthermore, the grapes dry 43% quicker inside than they do outside.

Kumar R, Verma SK, Sharma VK painted the absorber plate of their solar dryer with nano- material embedded black paint[7]. Black paint was sprayed onto one set of absorber plates, and a black paint containing 1 percent graphene nanomaterial was painted onto a second set of absorber plates. During the procedure, ambient air was drawn from a circular inlet section using a centrifugal blower powered by a 2 kW three-phase, 220 V alternating current motor. It was found that at a duration of 12 hours and an air speed of 1 m/s, the maximum efficiency values

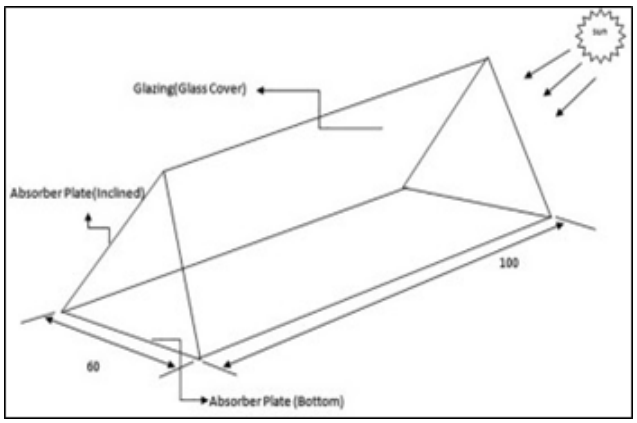



**Figure 4.** Experimental setup for effect of nanomaterial embedded paint[7].



**Figure 5.** Experimental setup for effect of glass thickness[8].

are found for the black paint coating at 43.15 percent and the 1 percent graphene nanomaterial at 48.23 percent. Graphene nano-material coating on the absorber plate increases the average thermal efficiency by 4.9 percent during daytime. The glass cover plate and mean absorber plate temperature reach their maximums during 12-13 hours at solar intensity levels between 930 W/m$^2$ and 980 W/m$^2$, but the mean absorber plate temperature increases when 1 percent graphene nanomaterial is added to the black paint coating.

Panchal HN, Shah PK conducted a study to determine whether the thickness of the glass panel used in the dryer had any effect on the efficiency of the solar dryer[8]. Glass panels of varying thickness (4 mm, 8 mm and 12 mm) were used. It was found that glass thickness did have an effect on the efficiency of the dryer. The glass panel of thickness 4 mm showed the best results. This is because the solar still generates more distillate when the glass cover thickness is smaller. For example, a 4 mm glass cover produces more distillate than an 8 mm or 12 mm glass cover. They also found that reduced thickness of the glass cover raises the water temperature inside the solar still and lowers the temperature of the inner glass cover.

Ringeisen B, Barrett DM, Stroeve P, were able to determine that the efficiency of solar dryers could be enhanced by using concentrators[9]. A solar concentrator is a device designed to focus and concentrate solar radiation, and its application can be both in the generation of solar thermal energy and in the generation of solar photovoltaic energy. Its operation is based on the use of

reflective surfaces, typically formed by a series of mirrors arranged in an aligned arrangement. The main purpose of these solar concentrators is to capture the greatest amount of solar radiation possible and direct it towards a small receiver. They did this by comparing the drying times of a control dryer against a dryer with a concave concentrator added to it, the dryer with the concentrator was found to have an average reduction in time of 21 percent. In order to create more ideal drying conditions, the internal dryer temperature was raised, and the relative humidity was decreased. It was also demonstrated that the quality of tomatoes was not adversely affected by the use of a concentrator. With little variation, dried samples with and without a concentrator had their titratable acidity, pH, color, Brix, lycopene, and vitamin C measured, and the results were similar which meant that the concentrator did not have any adverse effect on the tomatoes.

Mani P and Natesan VT[10] compared even span roof vs parabolic roof (vs open sun drying) in active as well as passive modes of convection. The dimensions of the dryers were: 1.5m × 1m × 1.02m. The drying chamber's effective base area measured 1.35 x 0.85 $m^2$. With the exception of the dryer's bottom, five layers of incredibly durable, low-density polyethylene sheet that is 200 micrometers UV stabilized and drip-proof covered the entire dryer structure. These sheets are lightweight, anti-corrosive, weatherproof, dust-resistant, low-cost, and have good resistance to moisture, impacts, and chemicals. They can also tolerate extreme temperatures up to 115°C. It shielded the product from dust, insects, and birds, among other things. The trays were made using stainless steel wire mesh and had the dimensions 1.4 × 0.9 m. The tray was placed at 0.5 m height from the bottom to ensure efficient heat distribution. In order to facilitate forced convection, a 12 V DC exhaust fan was mounted above the dryer to remove moist air continuously. A 25 W solar PV module was used to charge the 12 V battery that powered the exhaust fan. Five 2,500 g samples of lima beans each were collected and stored for drying in a parabolic and even span of open sun drying, forced convection, and free convection. In the even span roof dryer, the weight of the lima beans decreased from 2,500 g to 900 g in 32 hours by forced convection and 36 hours by free convection; in the parabolic dryer, this process took 28 hours by forced convection and 32 hours by natural convection. 40 hours were needed for open sun drying. The moisture content of Lima beans was reduced from 75 per cent (w.b.) to 11 per cent (w.b.). The active mode parabolic dryer was estimated to have the maximum thermal efficiency of 14.7 per cent, while the passive mode even span dryer had the lowest thermal efficiency of 12.03 per cent. The quality produced by the parabolic forced convection drier was found to be superior to that of products dried in traditional dryers and in the open sun. The product could be stored for a longer amount of time since it dried using a forced convection parabolic roof drier, which had a lower moisture content than any other method.

## 4.0 Conclusion

This review's investigation of solar dryer technologies demonstrates how significantly they can be used to address the problems with traditional drying techniques. The wide variety of solar dryer configurations and designs that have been discussed highlights how versatile these systems are for different agricultural products, climates, and contexts. In addition to lowering reliance on fossil fuels, solar drying's sustainable and environmentally beneficial qualities help to lessen the negative effects that conventional drying methods have on the environment. The documented developments in solar dryer technology- such as increased performance, increased efficiency, and creative designs by using various methods such as concentrators, nano-material embedded paint, use of fins etc.- showcase how these systems are always evolving. For example, Indirect natural convection solar drying technique was used to dry banana slices. The drying efficiency was 31.5%. It not only reduces drying time but also produces a better-quality product. For solar dryers with V shape corrugations on the collector plate product dried 43% quicker than open drying. Black paint containing 1% graphene nanomaterial was coated on absorber plate of solar drier. It increases the efficiency by 4.9% during daytime. The quality produced by the parabolic forced convection drier was found to be superior to that of products dried in traditional drier or open sun drying[11]. The moisture content of product was reduced from 75% to 11%.

These insights can be used by both researchers and practitioners to guide upcoming advancements and applications in the field. Furthermore, the financial

advantages of solar drying, such as lower operating costs and higher revenue generation for users, highlight the technology's potential to support sustainable development objectives.

## 5.0 References


1. Chauhan YB, Rathod PP. A comprehensive review on solar dryer. Int J Ambient Energy. 2018; 41(1):1-28. https://doi.org/10.1080/01430750.2018.1456960
2. Jangde PK, Singh A, Arjunan TV. Efficient solar drying techniques: A review. Green Energy for Environmental Sustainability. 2022; 29(34):50970-83.
3. Erin EM, Eva PE. SELCO credit union: A case study in quantifying the environmental impacts of design for deconstruction; 2014. https://doi.org/10.17831/rep:arcc%25y357
4. Lingayata AB, Chandramohana VP, Rajua VRK, Medab V. A review on indirect type solar dryers for agricultural crops - Dryer setup, its performance, energy storage and important highlights. Appl Energy. 2020; 258:114005. https://doi.org/10.1016/j.apenergy.2019.114005
5. Lingayat A, Chandramohan VP, Raju VRK. Design, development and performance of indirect type solar dryer for banana drying. Energy Procedia. 2017; 109:409-16. https://doi.org/10.1016/j.egypro.2017.03.041
6. Pangavhane DR, Sawhney RL, Sarsavadia PN. Design, development and performance testing of a new natural convection solar dryer. Energy. 2002; 27(6):579-90. https://doi.org/10.1016/S0360-5442(02)00005-1
7. Kumar R, Verma SK, Sharma VK. Performance enhancement analysis of triangular solar air heater coated with nanomaterial embedded in black paint. Mater Today Proc. 2020; 26:2528-32. https://doi.org/10.1016/j.matpr.2020.02.538
8. Panchal HN, Shah PK. Effect of varying glass cover thickness on performance of solar still: in a winter climate conditions. Int J Renew Energy Res. 2011; 1(4):212-23.
9. Ringeisen B, Barrett DM, Stroeve P. Concentrated solar drying of tomatoes. Energy for Sustainable Development. 2014; 19:47-55. https://doi.org/10.1016/j.esd.2013.11.006
10. Mani P, Natesan VT. Experimental investigation of drying characteristics of lima beans with passive and active mode greenhouse solar dryers. J Food Process Eng. 2021; 44(5). https://doi.org/10.1111/jfpe.13667
11. Sandali M, Boubekri A, Mennouche D. Improvement of the thermal performance of solar drying systems using different techniques: A review. J Sol Energy Eng. 2019; 141(5):1. https://doi.org/10.1115/1.4043613


## Abbreviations

db - Dry Basis
RTD – Resistance Temperature Detector
w.b. – Wet Basis
Tco,d – Dry Bulb Temperature of Air At Collector Outlet ($^0$C)
T1,d – Dry Bulb Temperature of Air At Tray 1 ($^0$C)
T2,d – Dry Bulb Temperature of Air At Tray 2 ($^0$C)
T3,d – Dry Bulb Temperature of Air At Tray 3 ($^0$C)
T4,d – Dry Bulb Temperature of Air At Tray 4 ($^0$C)
T5,d – Dry Bulb Temperature of Air At Tray 5 ($^0$C)
T1,w – Wet Bulb Temperature of Air At Tray 1 ($^0$C)
T5,w - Wet Bulb Temperature of Air At Tray 5 ($^0$C)