A REVIEW ON THE SOLAR DRYERS

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Abstract

Crop drying is crucial for agricultural uses that require preservation. Either a synthetic mechanical drying process powered by fossil fuels is used, or the crop is exposed to direct sunlight. While the second approach is completely dependent on the weather, the first method is expensive and bad for the environment. Contrarily, using a solar dryer is more cost-effective and effective.[1] Certain solar dryers function without the use of fossil fuels or the electrical grid. The current condition of various types of solar dryers that are often used nowadays is presented in this paper. We talk about the indirect, direct, and mixed mode dryers that have demonstrated promise for drying agricultural products in tropical and subtropical regions. The numerous modelling approaches for the solar dryer system are the main topic of this review paper.[2]To create, improve drying efficiency, analyse, and forecast the performance of various types of sun drying systems, modelling approaches are crucial. A continual application of relatively modest heat is typically required to dry agricultural items like coffee, tobacco, tea, fruit, cocoa beans, rice, nuts, and lumber. Crop drying has traditionally been done by open-air drying in filtered sunlight or by burning wood and fossil fuels in ovens. [3]However there are drawbacks to these approaches. The latter is vulnerable to the variety and unpredictability of the weather, while the former is expensive and harmful to the environment.

Keywords: solar dryer, infestation, feasibility, moisture, humidity, agriculture, vegetable.

I. Introduction

Due to the fast-growing populations in their separate countries, the majority of developing nations cannot resolve their food issues for the full populace. This high population growth directly affects the balance of food. Due to inadequate processing methods and a lack of storage facilities, the quality and quantity of food grains are declining. Reducing food losses during production is essential to maintaining the proper balance between food supply and population growth [9]. It's challenging, though, to make the most of small farmers' capacity for food production in rural locations. Drying has evolved into one of the primary processing methods used to preserve food goods in sunny places as a solution to the issue. Traditional open-air drying does have certain drawbacks, though. Scientists and researchers have been searching for the best solution to this issue for the past few years[4]. For agricultural crops, they created numerous types of solar dryers and have strived to further improve them. Solar radiation is abundant on Earth. The utilization of solar energy has grown in popularity recently. Many processes, including drying, heating, cooking, and distilling, can be powered by solar energy. [5]Solar energy is divided into electrical and thermal uses in terms of energy use. For farmers in many underdeveloped nations, using solar thermal systems to preserve grains, fruits, and vegetables is practical, affordable, and optimal. The first stage of the drying process involves applying heat to the surface of the object being dried at a constant rate. The second stage entails reducing the drying rate[10]. A sun dryer is useful for drying goods, vegetables, and grains so that they can be kept for a long period in storage. The former has many benefits over the latter when comparing solar drying versus open sun drying. For instance, solar drying improves product quality. Many agricultural commodities are dried using solar dryers of various shapes and sizes.

As a result, choosing a dryer is crucial in this industry because the financial aspect must also be considered. Researchers are currently working to reduce the amount of fuel used in solar drying. [12]The demand for energy can be effectively met by renewable energy. Solar power is the most dependable and environmentally benign source of electricity. In the agricultural sectors, we can use it for solar PV and solar thermal applications to pump and dry crops. The process of drying is crucial for agricultural products' preservation [15].

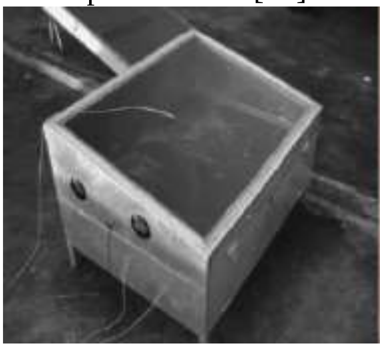

Figure 1: Direct solar dryer Figure 2: Indirect solar dryer

Direct sunlight is used by the direct solar drier to dry. Its design is straightforward, it requires little operation or maintenance, and it can dry modest amounts of crop. The direct solar drier is therefore designed for smallholders. [17]The direct solar dryer system is depicted in Fig 1.

Barnwal and Tiwari created this device, which has a 100 kg capacity, in 2008. This method of drying Thompson seedless grapes was used.

The indirect solar dryer system is depicted in Fig. 2. It consists of an air collector, a solar radiation collector, a backup heater, a circulation fan, and a drying cabinet. The most recent drying method is indirect solar drying. Compared to direct solar drying systems, it is more effective [19]. The ambient air is heated using collectors (flat plate or concentrated solar collector) in the indirect solar drying process. The cabin where the product is stored has this heated air flow.

II. Literature

Types of solar dryers:

Open sun drying:

In tropical and subtropical regions, thin layers of the crop are stretched out on trays, mats are covered with shade, and the product is exposed to wind and sunlight to dry. The stages of processing, the location of drying, or the sensitivity to sunlight radiation are used to categorise sun drying techniques.[20] For huge quantities of materials produced by big businesses, the open drying technique is not appropriate. In addition to the drawbacks of higher labour costs, more space requirements, and poorer product quality, it also requires a labour-intensive process before the goods are prepared for storage [22]. Environmental factors like solar radiation, wind, and other ambient circumstances might affect open-air drying. Due of numerous drawbacks, including lower quantity brought on by wind, waste, rainfall, and animal and anthropological obstruction, it frequently causes the items to degrade. Remoistening can occur if the crop is stored overnight and exposed to rain under cover [20]. Due to significant losses caused by insect infestation, enzymatic reactions, the growth of microorganisms, and

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mycotoxin augmentation due to the relatively long drying process, there is a discernible decline in product quality. [24]Moreover, uneven drying causes agricultural products to deteriorate while being stored. In humid tropical and subtropical regions, where agricultural food products must be dried throughout the rainy season, serious drying issues develop.

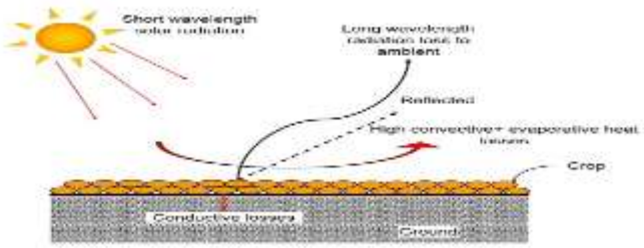

Figure.3 open solar dryer

Direct solar dryer:

A good substitute for open-air sun drying is solar drying. The tent and box dryers were created by the farmers themselves using materials that were readily available in their area for the on-farm drying of small quantities of fruits, crops, and vegetables. A transparent cover is utilised in this type of solar dryer to cut down on heat losses while also providing the product with strong protection from rain and dust. Ascending air forces provide the aeration needed to remove the evaporated water.[30] It is impossible to avoid infestations in this process, though. Very few farmers in many nations are able to generate 80% of crops during the growing season. The box type or cabinet dryer is the best illustration of a direct-type solar dryer. In locations that receive direct sunlight for longer stretches of the day, a direct-type solar drier is frequently employed [33]. Here, the drying cabinet is made of pressed wood that is 1 cm thick and is completely insulated on the inside, back, and bottom walls with glass wool. A big glass sheet is placed over the angled front wall to let sunlight through. For an indirect manner of dryer application, this transparent wall may be covered with an opaque and insulated sheet. [22]A fan draws damp air out of the dryer through exhaust openings on the back side. A centrifugal blower is used to move hot air from the solar collector into the chamber through the front wall's lowest portion.

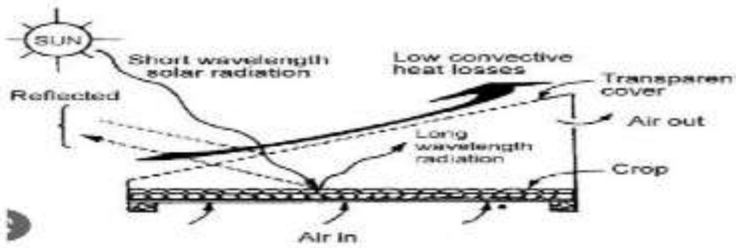

Figure.4 Direct solar dryer

Indirect solar dryer:

In an indirect solar dryer, the sun's heat is first gathered by the solar collectors and is then delivered onto the dryer cabinet, where is the drying occurs [23]. After being heated, the solar air that enters the chamber is forced to pass over the soggy crops. The heaters for the air are linked. In a solar cabinet-type dryer, food products are dried using the fundamental principles of the reverse flat plate collector [20]. Here, the air that enters the chamber is heated by a solar air heater. After being heated, the air becomes warm and humid before passing through an outlet. [22]This type of dryer is superior to other dryers in terms of resolving various energy balance-based calculations. Also, it performs better than other dryers of the traditional cabinet style. the effectiveness of an indirect-type solar dryer and discovered that the dryer may still produce well under adverse weather conditions. Moreover, due to its inexpensive requirements, it is perfect for small farms [20].

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In a different study, the effectiveness of an indirect-type multi-self-dryer for fruits and vegetables was examined overall performance of an indirect-type multi-self-dryer for fruits and vegetables [21]. This study demonstrates that by raising apparent drying rate and drying efficiency, high-quality dried items can be produced. Fick's equations and the diffusion theory were streamlined to create a mathematical model, which produced results that were more than sufficient. [20]The chamber temperature and the thickness of the drying samples are the primary considerations in this type of drying process.

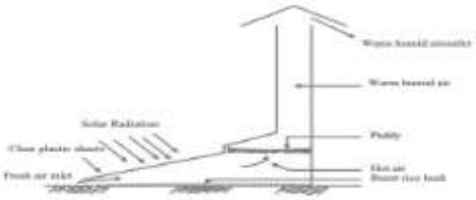

Figure.5 Indirect solar dryer

Mixed-mode solar dryer:

The isometric representation of a mixed-mode dryer is presented in the mixed-mode solar dryer has no moving parts, which is why it is called the passive dryer [30]. This type of dryer acquires energy from the rays of the sun that enters through the collector lustring. The inside surface of the collector is painted black, and the sun's rays are harnessed by trapping the heat of the air that is collected inside the chamber.[31] An active mixed-mode dryer for drying rough rice has been created, examined, and tested. They have a drying chamber, an inlet and exit bin, and a plenum chamber in their drying system. There are two experimental uses in this system [33]. Both the first and second applications investigated the mass flow rate and discharge interval time. The second one also had moisture content. According to the findings, crop drying has a good mass flow rate effect and discharge rate. Also, this technology produces results that are satisfactory in terms of drying effectiveness and moisture content. The system's greatest efficiency was 21.24%, and the drying process used 6-8% of the system's total energy [20]. 13% was the final moisture content. In another effort, a straightforward mixed-mode solar dryer was conceived and designed. This method, which operates on the basis of a thermal test procedure, is appropriate for cylindrical potato sample drying investigations indoors [21]. When it comes to improving performance in terms of achieving the lowest moisture content ratio during drying time, this type of dryer can be used. The cylinder-shaped potato samples can be dried inside using this method, which operates on the basis of the thermal test procedure. [2]In order to achieve the lowest moisture content ratio during drying time, this type of dryer can be employed to improve performance.

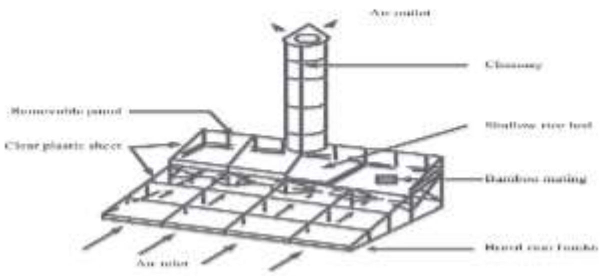

Figure.6 Mixed mode solar dryer

Natural convection solar dryer (passive mode solar dryer):

A natural convection solar dryer requires the least amount of energy to regulate the drying temperature. Its drying rate is constrained, though. Due to its low cost, this type of solar dryer undoubtedly plays a significant part in the drying industry. Its ease of upkeep and use has also contributed to its popularity.[20] In comparison to forced convection dryers, natural convection solar dryers are more

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appropriate and among the more traditional dryer kinds. These components are interconnected in a series to form a system that can achieve drying rates that are highly good. For drying rough rice, a sun drier with indirect natural convection has been developed. [21]They also created a method and talked about the dryer's performance. A solar air heater can be used to increase the dryer's drying capacity.

Wood, glass blades, and locally accessible metals are used in the design and construction of a direct-type natural convection solar dryer. The drying of agricultural products has been tested experimentally with this dryer.[40] It's critical to establish certain characteristics, including ambient temperature, drying system air mass flow, and incident heat fluxes, in order to forecast drying efficacy. The capacity of the natural convection solar drying system is constrained. Furthermore, a little amount of float used to induce air movement inside the dryer causes the drying rate to be delayed and extremely reliant on atmospheric circumstances, which lowers the quality of the drying goods, especially in bad weather conditions [30].

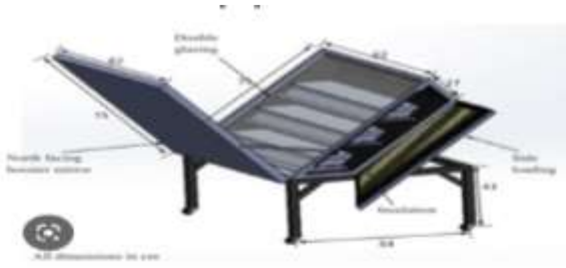

Figure.7 Natural convection solar dryer

Greenhouse solar dryers:

For efficient year-round solar energy usage in agricultural production, the bulk-curing/greenhouse system, also known as the greenhouse solar system, is a sizable solar collector in which the curing and drying process, or plant production process, is carried out.

Huang and Toksoy successfully used such a system to regulate the tobacco bulk curing process using a microcomputer in order to maximise the use of solar energy.[45] Studies on development and yield demonstrated that solar barn-grown seedlings adapted to totally automatic transplanting and that these seedlings produced greater growth and production. In the solar greenhouse dryer, many thermal modelling techniques are applied. Products in the greenhouse drier exhibit both heat- and mass-transfer phenomena during the drying process.[41]Sunlight enters the greenhouse drier through the cladding material, heating the product in a practical way.

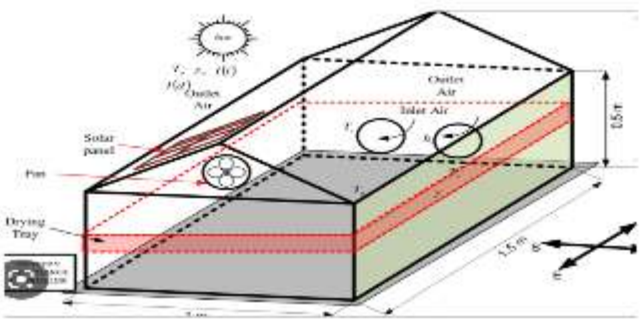

Figure.8 Greenhouse solar dryer

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Cabinet type solar dryers:

Three components of a drying system were built and tested: a solar collector, a solar drying cabinet, and an air blower [26]. The results revealed that the temperature of the air inside the cabinet has the greatest impact on the drying rate; the effect of speed variations on the air inside the cabinet is negligible and can be ignored; and because the relative humidity of the air leaving the cabinet was low (between 25% and 30%), there is no need for high velocities [48]. Using a few generalised but useful assumptions, a transient analysis of a cabinet-type solar dryer was conducted, and the model predicts the instantaneous temperatures inside the dryer as well as the moisture content and drying rates.[20] The analysis was performed for loads ranging from 10 kg to 40 kg of drying product as well as for no load[46]. By formulating the transient equations for each component of the system and attempting to solve them using periodic analysis, an attempt was made to study a cabinet-style solar dryer. The findings from the theoretical and experimental data were provided, and the model was able to predict the instantaneous temperature within the dryer as well as the moisture content and drying rates [26]. By resolving the numerous energy balance equations, the thermal performance of the new proposed dryer was examined and contrasted with that of a traditional cabinet drier. The reverse flat-plate absorber dryer was determined to provide the best performance [47].

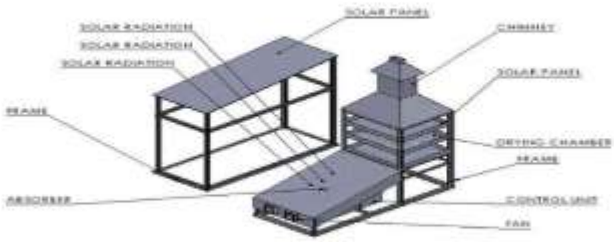

Figure.9 Cabinet type solar dryer

Tunnel type solar dryers:

The modelling and thermal performance findings for the collector of a semi-cylindrical Sun Tunnel Dryer (STD). For the Delhi environment (28.58 N latitude), the performance was calculated for both forced and natural circulation modes, as well as for various STD tilts [50]. Because it offers some advantages over the already prevalent forced circulation type STD, the development of the natural circulation type STD is quite crucial. [51] Originally designed for usage in arid regions, a multi-purpose solar tunnel drier with a tiny centrifugal blower, a collector, and a tunnel drying chamber was modified. Originally designed for use in arid regions, ginal was modified by Amir et al. to permit operation in tropical climates, with a biomass furnace and heat exchanger included into the solar drying system to heat the drying air on overcast and rainy days [45]. Investigations further revealed that it was possible to dry the products to the final content needed for storage and marketing even during the rainy season, and the modular system allows adaptation to different farm sizes as well as cooperative use, with results showing that the drying time of cocoa, coffee, and coconut could be reduced by up to 40% compared to natural sun drying [37].

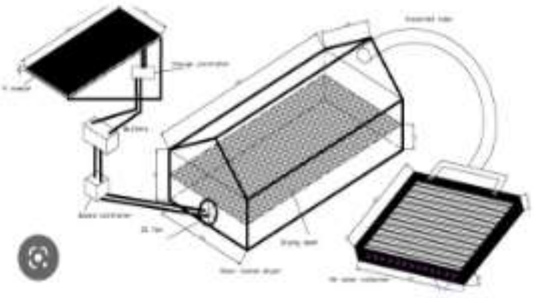

Figure.10 Tunnel type solar dryer

Solar chimney dryer:

A solar chimney is used to dry agricultural products. A prototype solar chimney was built to assess the technical feasibility of this drying device, in which the air velocity, temperature, and humidity parameters were monitored as a function of the solar incident radiation, and food drying tests, based on theoretical and experimental studies, assured the technical feasibility of solar chimneys used as solar dryers for agricultural products. Solar chimneys used as agricultural product dryers [51].

Afriyie et al. described an experimental investigation into the performance of a solar crop dryer with a solar chimney and no air preheating. The cabinet dryer was tested with a normal chimney and then again with a solar chimney; the trials were carried out with the roof of the drying chamber inclined further to form a tent dryer. The results demonstrated that a solar chimney can increase the airflow rate of a direct-mode dryer, particularly when well designed with an appropriate angle of drying-chamber roof[47].design and performance of a low-cost, simple solar dryer coupled with a vertical flat plate collector chimney for drying 20 kg of field crops harvest high moisture paddy. [24]During the winter months, the experiments revealed an average rise in air temperature of 21.8 C and 27.1 C for the inclined and vertical collectors, respectively, with an average air flow rate of 0.6707 m3/min (0.22 m/s) through the chimney, and a 33%

reduction in air flow rate was observed with a 7 cm depth of grain (20 kg) in the dryer when the average rise in air temperature in the inclined collector was increased to 68.5 C [36].

Grape drying:

Several solar dryers designed specifically for drying grapes on a large scale [51]. Many popular solar dryer varieties, typical models, and traditional methods for drying grapes were presented, and the technical and economic results demonstrated that solar drying of grapes is quite feasible, and the fact that commercialization of solar drying of grapes has not gained momentum as expected may be due to high initial investment and low capacity of the dryers. the development trends of solar dryers used for drying grapes [52]. Several typical installations, including traditional methods, were presented, and the technical and economic results indicated that solar drying of grapes is feasible; however, farmer acceptance of solar drying was still very limited, which could be attributed to the dryers' small capacity and long payback period, or to socio-cultural factors. in a natural convection solar dryer, under a tunnel greenhouse and in open sun.[27]These tests revealed that the solar tunnel greenhouse drying process is both satisfactory and competitive with natural convection solar drying . For drying Thompson seedless grapes, a hybrid photovoltaic-thermal (PV/T) greenhouse dryer with a capacity of 100 kg [49]. To evaluate heat and mass transfer for the proposed system, grapes were dried in both open and shade conditions, and various hourly experimental data, such as moisture evaporated, grape surface temperatures, ambient air temperature and humidity, greenhouse air temperature and humidity, and so on, were collected. to assess heat and mass transfer in the proposed system [20]. Twenty-two experiments were carried out to investigate the effect of drying air temperature and velocity on Sultana grape thin layer drying. Eight different thin layer mathematical drying models were compared based on their coefficient of determination to estimate solar drying curves, and the results revealed that a two-term drying model with a correlation coefficient(r) of 0.979 could satisfactorily describe the solar drying curve of Sultana grapes [32].

III. Conclusion

This paper examines the design, performance, and application of various types of solar dryers on the market today. Direct, indirect, mixed-mode, active, and passive solar dryers are all investigated.[20]This paper focuses on solar dryer models that can produce high-quality dried goods. The best solutions to the problems associated with traditional drying (i.e., open sun drying) are discussed, as are methods for creating simple, inexpensive, and low-cost solar dryers [32]. We also talk about some of the environmental consequences and how they can be mitigated.

The development of solar crop dryers is the best way to overcome the disadvantages of traditional open sun drying and the use of fossil fuels. In addition to reducing the use of fossil fuels [50], the quality of dried crops is improved, and product loss is reduced significantly.

The following are the most recent solar dryer technologies that have been reviewed:

• The status of solar dryers in developing countries was reviewed.

• A review of the design, development, and performance evaluation of various types of solar dryers was conducted.

• Natural convection and forced convection dryers, direct and indirect type dryers, integral dryers, greenhouse dryers, cabinet dryers, tunnel dryers, and mixed mode dryers were evaluated in terms of design and performance.

• Special consideration was given to solar drying technologies, which allow crops to be dried during non-sunny hours. One such technology that was briefly discussed was a desiccant-based solar drying system.

• Solar dryers designed specifically for a specific crop, such as grain dryers, grape dryers, onion dryers, potato dryers, and so on, were reviewed, along with their design, performance evaluation, and system simulation results [47].

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