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A Review on Solar Dryer with Active and Passive Technique

Gadiya Akshay Shamlal[1]
akshaygadiya111@gmail.com

Deshmane Somesh Bhagwat[1]
somesh.deshmane30@gmail.com

Gadhe Rahul Ansiram[1]
rahulgadhe2244@gmail.com

Gawali Omkar Anil[1]
omkargawali228@gmail.com

A. N. Shaikh[2]
alimoddinnshaikh@gmail.com

[1]Student and [2]Assistant Professor, Department of Mechanical Engineering, JSPM Narhe Technical Campus, Narhe, Pune, India

Abstract— **Drying of agricultural products is an energy demanding process. Solar energy as an alternative source is becoming more popular, especially in developing nations, due to high costs, unavailability of fossil fuels, and environmental hazards. The utilization of clean and green energy resources in the sector of drying agricultural products has increased in response to the rising environmental concerns. A solar dryer combined with a thermal energy storage system is reasonably efficient for continuous and consistent drying of agricultural produce in the temperature range of 40 - 75°C, which is required for drying most agricultural items. Traditional drying systems require fossil fuels; therefore, these dryers have become a natural alternative to replace it. For the last several decades, a large number of researchers have studied the use of a solar dryer to dry crops and food products. This review study focuses on the significant contributions made in the field of solar drying systems thus far, as well as the most current breakthroughs in drying technology. Solar dryers that provide drying during the hours when the sun is not shining have been specifically noted. Some different methods have also been considered, such as the use of phase change materials (PCMs) and desiccant materials to increase the dryer's performance and efficiency.**

Keywords – Food Drying, Solar Energy, active technique, passive technique, desiccant material.

I. Introduction

For thousands of years, agricultural and other products have been dried in the open air by the sun and wind. The goal is either to preserve them for later use, as in the case of fruit, or to use them as part of the manufacturing process, as in the case of wood, tobacco, and washing. Modern industrial dryers with boilers to heat incoming air and fans to push it through at a faster rate have mostly replaced open air drying in industrialized regions and industries. Modern industrial drying is more efficient than open-air drying, requires less space, and produces a higher-quality product. However, the equipment is costly and takes a significant amount of fuel or power to function.

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Food losses during harvesting and selling should be avoided to maintain the balance between population increase and food availability. Poor processing methods and a lack of storage facilities have a negative impact on the quality and quantity of agricultural output. On the agricultural sector, several emerging countries have suffered significant losses. Fruit and vegetable post-harvest losses in poor nations are estimated to be 30–40 percent of overall production [1].

One of the most essential methods for preserving fruits and vegetables is drying. The oldest method for removing water is drying, which is utilized in a variety of applications such as drying wood pulp for manufacturing paper, drying for preserving food, and drying construction materials. Solar dryers are mostly used to dry fruits and vegetables, with the end product being clean and hygienic if necessary are created during the setup. It also consumes less energy and takes up less space. The major benefit of a solar dryer is that it helps the environment by not emitting carbon monoxide, carbon dioxide, nitrogen oxides, and other pollutants that internal combustion engines and power plants do It also improves product stability, lowers packaging issues, and decreases product weight and shipping costs [1].

The most common drying process is convective drying (heating by convection between hot air and the product surface), also known as drying by flow heated air circulating on the top, bottom, or both. It might be on one side, both sides, or over its entire mass. The product is heated by hot air, which also transports the released moisture to the atmosphere. As a result, drying psychrometry is crucial since it relates to the characteristics of the air–vapor combination that govern the drying function. The sun's rays directly heat the product, and moisture is eliminated by natural air circulation due to density variations in direct solar drying, also known as "sun drying differences." [2].

The advantages of both direct and indirect solar dryer systems are integrated in the hybrid solar dryer, which creates cumulative heat flux by combining the incident direct solar heat flux with the pre-heated drying air in the solar collector. This enhances the drying process [3].

Improving both the solar collector plate and the drying cabinet of existing hybrid solar-driven drying systems might solve the issues associated with high drying costs, non-uniform drying rates, and lower efficiency of solar drying systems. A newly improved passive-mode hybrid solar dryer was created against this backdrop. In addition, a typical active-mode hybrid solar dryer was built. Modified passive-mode and active-mode hybrid solar dryers were presented as viable replacements to traditional open-sun drying [4]. To counter the drawbacks of open-air drying, several solar dryer designs have been developed, and these attempts have necessitated better technology [5].

The spherical dome, hyperbolic paraboloid, Quonset, modified Quonset, gothic arch, mansard roof, gabic even span, gabic uneven span are all examples of solar greenhouse dryer forms [6]. The three heat transfer mechanisms, as well as the characteristics of solar radiation, explain the operation of the solar dryer and the physical events that occur within it. Sun energy incident on the collector's semi-transparent cover (polycarbonate) is transmitted in the visible range, while radiation in the longer-wavelength infrared portions of the electromagnetic spectrum is effectively blocked The polycarbonate reflects a portion of the solar radiation, while the other portion is transferred to the absorber plate, raising its temperature, transferring heat to the air via convection and radiation, causing the greenhouse effect, changing its density, and pushing it into the cabinet and chimney to induce air flow through the dryer. We utilized the ANSYS-FLUENT algorithm to solve the physical phenomena [9].

Solar energy may also be used to generate low to medium temperature heat, with temperatures ranging from 80 to 150 degrees Celsius [11].

Mathematical modelling is essential for the implementation of dryers that are simple to use while also improving product quality and saving energy [10].

Food and other items that absorb moisture are best preserved by drying. Drying consumes a significant amount of energy, having uses in agriculture, bio-oil, construction, paper and textile manufacturing, chemical manufacturing, and pharmaceutical manufacturing etc. [13].

The air flow in natural convection solar dryers is caused by buoyancy-induced air pressure, and the drying process takes several days, whereas a cabinet drier takes three to four days to dry grapes. Air flow is delivered by a fan in forced convection solar dryers, which can be powered by electricity/solar module or fossil fuel. Solar dryers are solar-powered machines that use the sun's energy to dry materials, particularly food. There are two general types of solar dryers: Direct and indirect'

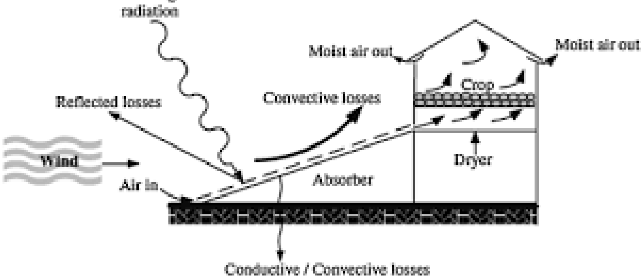

Figure 1. Natural Convection [1]

Figure 2. Solar Dryer [2]

A. Active Method

In this method there is a external force is applied to run the system it is also known as Forced convection. Forced convection or hybrid solar dryers are other names for active solar dryers. Throughout the drying process, sufficient air flow may be given in the dryer to manage temperature and moisture in a wide range of values, based on weather conditions.

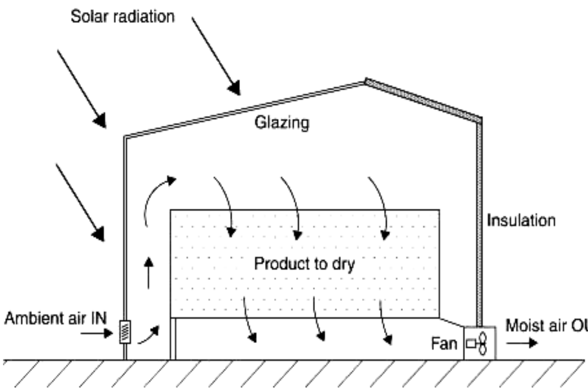

Figure 3. Active Method [4]

B. Passive Method

In this method there is a no external force is applied to run the system it is also known as Natural convection. In this approach, ambient air is heated in a flat plate collector before being blown into the cabin where the items are stored. Moisture is extracted from this sort of drier by convection as well as diffusion.

C. Principle of Drying

The main phenomena that regulate the drying process via hot air circulation are provided in order to introduce or refresh the reader's memory on drying principles. These concepts apply to mechanical conventional drying in general, and mostly to indirect solar drying in this case. In general, traditional drying principles and occurrences are unaffected by the energy source.

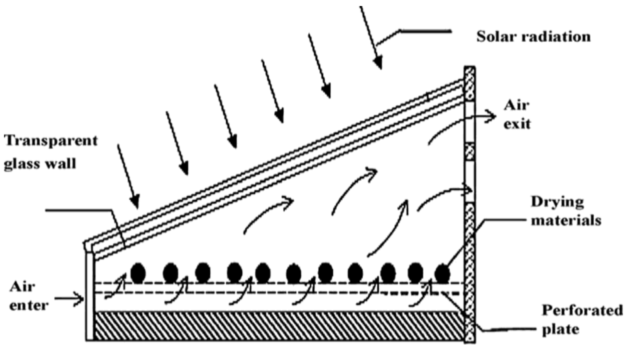

Figure 4. Passive Method [5]

II. Importance Of Solar Dryer

Drying has been used to preserve fruits, other products, meat, and fish for ages by people from diverse countries. Hay, copra, tea, and other non-food crops that provide income benefit from drying. Solar energy, which is now widely available, may considerably improve the availability of all of these agriculture products. It's worth mentioning that drying was basically the sole technique of food preservation until near the end of the 12th century, when canning was invented. (Bean et all, 2002).

According to Ikejiofor (1985), the energy input for drying is lower than that required to freeze or can, and the storage space required is less than that required for canning jars and freezer containers. It was also mentioned that drying has just a little impact on the nutritional content of food.

Furthermore, food scientists have discovered that lowering the moisture level of food to 10 to 20% prevents bacteria, yeast, mould, and enzymes from rotting it (Gallali, et al., 2000). When the inside temperature of food reaches 145°F, microorganisms are successfully eliminated. Dried food's flavour and most of its nutritional content are retained and concentrated. Dried foods are simple to store and transport because they don't require any extra equipment. Traditional open-air sun drying processes for vegetables and other food crops are unsuccessful since the items decay quickly. According to studies, food items dried in a solar dryer outperform those sun dried in terms of flavour, colour, and mould counts. Solar dried fruits are high-quality products that can be stored for long periods of time, transported easily and affordably, and have a high nutritional content. As a result, the design and construction of a residential solar dryer are shown in this project work.

A. *Materials used for dryer*

The solar dryer has been designed and created by many authors using various materials. Aluminum sheet, wood, cast iron sheet, polycarbonate, and hybrid composite are among the materials utilized in the solar dryer. In the solar dryer, insulating materials play a significant role. In the dryer, cast iron is utilized as a storage container for hot fluid/air.

III. Classification Of Solar Dryer

Because there are so many various designs, many of which are based on assumptions, it's difficult to identify solar drying equipment precisely. They may be classified by a number of factors, including the kind of dryer, the operating temperature, and the material to be dried, to mention a few (e.g. batch or continuous).

Solar dryers can be characterised as passive or active depending on the drying process: (a) Passive dryers are heated directly from the sun's rays with or without natural air circulation, and (b) Active (or forced convection) solar dryers circulate hot drying air through a ventilator.

a. *Passive solar dryers*

Crop drying by direct or passive methods is used in many Mediterranean, tropical, and subtropical climates, mainly in Africa and Asia, as well as in small agricultural communities. Passive solar dryers are "hot box" equipment with a transparent cover that exposes the product within to sun radiation. Natural convection, the dryer's clear cover, or a solar air heater are all used to heat the space.[2]

b. *Active (Forced convection) solar dryers*

Solar dryers with forced convection can dry large amounts of material (also known as active solar dryers). They either use a direct absorption system with clear covers or a solar collector-connected indirect solar heat system. They are sometimes hybrid systems that, when available, use supplementary energy sources such as conventional fuels, biomass, gas, and so on, avoiding some of the drawbacks of passive solar dryers. Because they require fans, ventilators for air circulation, and piping loops, forced convection sun drying systems are more difficult and costly than passive systems Belghit et al. (1997) gives a mathematical model for simulating the behavior of solar crop dryers in forced-mode operation [2].

Products and Their Drying Temperature are-

1. Chillies

The temperature of chillies which drying in between 60^0C-75^0C. The temperature should not exceed 100°C. 80 °C is ideal for drying chillies [17].

2. Amlas

The effect of drying conditions on the Amla fruit was studied in this study. The experiment has been carried out in a testing oven drying at temperatures of 40 and 50 degrees Celsius. Amla slices with a thickness of 0.5 cm and a length of 0.1 cm were dried. Moisture loss and acidity were observed in the food items. The study indicate that temperature has a major impact on moisture content, acidity, and the microscopic characteristics of dried products. Moisture loss was greater at 50 °C than it was at 40 °C during drying. The acidity of dried Amla powder formed at a drying temperature of 40 °C, despite the fact that it was greater than 50 °C at the other end. According to X-ray diffractometer analysis, the microstructure of Amla was crystalline-amorphous. Fourier Transform Infrared Spectroscopy identified polyphenols, pectin, and ascorbic acid components in Amla fruit as O-H, C-O, and C=O forms. The temperature of the oven drier had a significant impact on the microstructure, according to a scanning electron microscopy investigation. [16].

3. Fruits

In the Fruits to prevent overheating and damage of the fruit, the drying temperature should be kept under control. Most fruits are dried at about 60-70 deg C. Fruits are dried until the optimum final moisture content is obtained (15 percent for conventionally dried fruits; 20-25 percent for osmotically dried fruits) (sugar treated fruits). The ideal temperature for drying food is 60 degrees Celsius. Higher temperatures will cause the food to cook instead of dry.

Recent efforts to improve sun drying have led to solar drying. The sun is used as a heat source in solar drying, but a specifically built dehydrator raises the temperature and air current to speed up the drying process. Food deterioration and mould are reduced when drying durations are reduced. [18].

4. Spices

Pre-heat the dehydrator in the Spices area with the thermostat set to 35℃ to 47℃. Temperatures as high as 52℃ may be necessary in humidified areas. After drying under cold running water and shaking to remove excess moisture, arrange the herbs in a single layer on dehydrator trays. [18].

5. Basil

Five different drying methods have been used to dry basil (Ocimum viride) leaves: microwave drying at power 3, oven drying at 110^{0}C, hot air drying at 100^{0}C, sun drying at 33oC, and ambient air drying at 28^{0}C [20].

6. Potato chips

Drying trials on potato slices were performed at 45–70℃ with air velocity of 1.60 and 1.81 m/sec. The drying temperature was shown to be the most effective parameter that determines the drying rate. In low temperatures, the effect of air velocity was more significant [19].

7. Rose Leaf

The Rose leaf drying Temperatures should be kept between 30^{0}C and 35℃ for drying [21].

8. Ginger

The recommended drying temperature for most food products is 60–70℃. This shows that the current solar cabinet dryer can effectively dry agricultural products like ginger [15].

IV. APPLICATION OF SOLAR DRYER

- Agricultural crop drying.
- Food processing industries for dehydration of fruits and vegetables.
- Fish and meat drying.
- Dairy industries for production of milk powder.
- Seasoning of wood and timber.
- Textile industries for drying of textile materials, etc,

Solar drying with using various product:

1. Red chili

The double-pass solar dryer for red chilli is being tested. The air flow rate and average solar radiation intensity were found to be 0.071 kg/sec and 566 W/ m2, respectively, in the experiment work. It took 24 hours to decrease the moisture content from 80 percent to 9.1 percent (wet basis) using a double pass indirect type drier (not including the night). In general, drying the red chile in the open sun takes 58 hours. The efficiency of the collector pick-up and drying systems was 38 percent, 47 percent, and 59.6 percent, respectively. Evaporative capacity was also found to be in the range of 0.15–24 kg/hr.

A performance study of the solar tunnel drier for drying red chilli was carried out. It lowers the moisture content from 75% to 5%. Throughout the project, the air velocity was kept constant at 0.5 m/sec. The intensity of solar radiation ranges from 300 W/m2 to 900 W/m^2. The performance of a 5-kilogramme red chile is tested in a single layer of solar dryer. The ambient temperature was 39.1 degrees Celsius, while the temperature within the chamber was 51.68 degrees Celsius [5].

The drying of Malaysian red chilli in the open and solar drying are compared. Within 30 hours, red chilli was dried from 80% (wet basis) to 10% (wet basis) moisture content. In the same conditions, open drying took 65 hours. The time required for drying using the solar dryer was found to be decreased by 49%. The average sun intensity and air flow were both kept at 420 W/ m2 and 0.07 kg/sec. The average evaporation capacity was 0.97 kg/hr, and the specific moisture extraction rate (SMER) was 0.19 kg/Kwh.

In Thailand, a large-scale greenhouse solar drier for red chilli is being studied. A parabolic polycarbonate sheet is used in the greenhouse solar drier. The dryer had a concrete floor surface of 8 m * 20 m and was supplied with 9 D.C fans for ventilation. In open drying, a red chile with a moisture level of 74 percent (wet basis) was dried in three days.. The solar radiation intensity ranged from 390 to 820 W/ m2. Chili dried in the greenhouse dryer had a nicer colour than chilli dried in the open sun. The payback period for a large-scale greenhouse drier is determined to be two years, and it has excellent economic and technical performance [18].

2. Turmeric

It is a user-friendly, low-cost mixed mode force convective type solar tunnel drier. The solar air heater's inclination was a significant benefit of this type of dryer for effectively capturing solar energy. The moisture content dropped from 0.779 (kg of water / kg dry matter) to 0.07 (kg of water / kg dry matter) after 12 hours of forced convection. It took 43 hours to dry in the open sun. The dryer's energetic efficiency was determined to be 49.12 percent, with an energy utilisation ratio ranging from 9.95 to 33.98 percent. To explain the behaviour of the turmeric, eleven mathematical models were used in the study. The energy consumption ratio was determined to be between 9.75 and 33.98 percent, while the dryer's exergetic efficiency was found to be between 23.25 and 73.31%.

It is intended as a solar turmeric dryer in a solar conduction dryer with a temperature of 39–51 C inside. The ambient temperature was between 25 and 28 degrees Celsius. Experiments on solid and sliced turmeric revealed that after 12 hours, the ultimate moisture content was 6.36 percent (wet basis) and 15.50 percent (wet basis) for solid and sliced turmeric, respectively, down from 78.65 percent (wet basis). The average effective moisture diffusivity for solid turmeric was 1.456*10-10 m2 s 1 and 1.852*10-10 m2 s 1 for sliced turmeric. The amount of curcumin in turmeric powder has been observed to fluctuate from batch to batch. In four distinct commercially available turmeric samples, the proportion was found to be between 1.06 percent and 5.70 percent. Heat processing of turmeric resulted in a loss of 27–53 percent of curcumin, with the greatest loss occurring when the turmeric was pressure cooked for 10 minutes. The rate of drying was considerably faster for sliced turmeric than for whole turmeric. The 60 percent drying rate of sliced and whole turmeric was the same (wet basis). The same sliced turmeric took 25.5 hours to dry in the open sun, and it was damaged by white spots of fungal growth. The solar communal dryer shows no signs of fungus development. Lewis, Page, Modified Page, Henderson, and Pabis were all examined in this study, and the Page model was determined to be the best fit for simulation [18].

3. Copra

It is investigated the performance of a double-pass solar air drier. In the sun dryer for Copra, a finned absorber was employed. During a 23-hour period, moisture levels ranged from 52.68 percent (wet basis) to 10.73 percent (wet basis) or 1.113 percent (dry basis) to 0.120 percent (dry basis). The open drying process takes 67 hours. The air flow rate was kept constant at 0.083 kg/s. The average drying rate for open drying was 0.055 kg/hr, whereas solar air drying was 0.191 kg/hr. The specific energy consumption (SEC) was determined to range between 1.184 and 10.779 Kwh/Kg. The efficiency and enhanced potential rate of the system were 39.47 percent and 87.98 J, respectively. In Indonesia, open sun drying and smoke-drying techniques are frequently employed to dry coconut. However, it has a number of drawbacks and detriments, including wind-blown trash, rain, bug infestation, and human and animal meddling.

The drying of Copra in a solar tunnel drier is being studied. The full load natural conventional sun dryer took 57 hours to reduce moisture levels from 52.8 percent to 8%, whereas the half load condition took 52 hours. When compared to open sun drying, the grade of copra obtained from (54.66 percent) is excellent (53 percent). In the solar tunnel drier, the average efficiency was determined to be 20%. In tests, the sun intensity was found to be 857 W/m^2 [18].

4. Grapes

They developed a numerical model and conducted an experimental study on grape drying in a chapel type mix-mode greenhouse solar system. Between 29.63 percent and 88.32 percent collector efficiency was observed. It took 128 hours to reduce the moisture level from 5.5 g/g (g water / g dry water) to 0.22 g/g (g water / g dry matter) during the drying process. The mathematical model was simulated using TRNSYS software. The experimental result was compared to the simulation data. The temperature inside the solar dryer was 55.97 degrees Celsius, while the temperature outside was between 24.54 and 35.71 degrees Celsius. The results were obtained using a model, and the experimental results are very close to the model results.

It is developed an explicit finite difference method to solve a mathematical model. The experimental result was compared to the simulation data. The temperature inside the solar dryer was 55.97 degrees Celsius, while the temperature outside was between 24.54 and 35.71 degrees Celsius. The results were obtained using a model, and the experimental results are very close to the model results.

In Udaipur, India, the Hemi-cylindrical type sun dryer was developed. The temperature inside the sun dryer was kept between 500 and 70 degrees Celsius. In the first three days, the moisture content dropped from 84.4 percent (wet basis) to 68 percent (wet basis). Further, the moisture removal rate increases, reaching 16.2 percent (wet basis) on the seventh day. Using the pretreatment, the drying time necessary to decrease the moisture content can be lowered [18].

5. Peanuts

To built a solar dryer to improve the quality of peanuts in Ghana, reducing moisture content to 5.25 percent from 25.85 percent in single layer drying and 32 percent to 4.25 percent in four layers drying. Peanuts were found to have a faster drying rate when they contained more moisture after four days.

For accelerated drying of peanuts, Athapol Noomhorn et al. designed a conduction dryer. As a heating medium, sand was used. The conduction dryer's performance was assessed in terms of peanut quality and drying time. At a rotational speed of 8 rpm, a feed rate of 7 Kg/min, and a temperature of 70 C, the best quality was observed. Because of the sand, peanuts have a low-quality index uniformly at high temperatures and a longer drying time. They get provided an empirical equation for materials with a high moisture content (100 percent dry basis and above). The equation was evaluated in a variety of drying conditions and compared to a commonly used drying equation [18].

6. Fish

It is designed a solar dryer for silver cyprinid fish in batches of 10 kg. Within 11 hours, moisture was reduced from 73 percent (wet basis) to 20 percent (wet basis). Drying the same number of fish in the open sun takes 18 hours. The drying system and collector were both 11 percent and 9.36 3.95 percent efficient, respectively. The drying rate constants for the top, middle, and bottom try were 0.146, 0.146, and 0.148

It is designed and tested a solar tunnel dryer for drying fresh fish weighing 50-100 kilogrammes per batch. Half of the tunnel dryer's base is used for air heating and half is used for drying. The temperature of the dryer could be raised by 5–30 C by increasing the air velocity to 0.2 m/sec. Moisture was reduced from 66.5 percent to 15.5 percent (wet basis) in 30 hours (wet basis).

The solar tunnel dryer for fish is under investigation. The solar tunnel drier was shown to have a faster drying rate than the open sun dryer. Throughout the drying process, the temperature in the solar tunnel stayed constant at 53.5 degrees Celsius. As a drying sample, fish with and without salt were employed. Fish without salt reduced their moisture content in the upper tray to 19.05 percent (dry basis) after 32 hours and to 19.90 percent (dry basis) in the lower tray. It took 37 hours to reduce the product's moisture level by 23.73 percent. Fish with salt reduce their moisture content to 19.29 percent (dry basis) in the upper tray and 19.63 percent (dry basis) in the bottom tray after 35 hours. In the open sun, it took 39 hours to dry, reducing the moisture content to 19.41 percent. (On a dry basis) [18].

V. Conclusion

This paper says that at various types of solar dryers, as well as their design, development, and performance. The drying of various products necessitates varied drying environments, as discussed in this study. When constructing a solar dryer, consider the intensity of solar radiation, relative humidity, ambient temperature, starting moisture content, and crop kinds. To achieve a better-quality result, air velocity and temperature must be adjusted according to moisture content and product to be dried.

Because of its faster drying rate, forced convective dryers are better for high moisture content products than natural convection dryers. The solar dryer may be operated at night and during low-intensity periods thanks to the thermal storage. Paraffin wax, rock, water, metal waste, and a combination of aluminium powder and paraffin wax were utilized by the majority of the researchers. Solar dryers with a mix-mode mode are more suited for many applications and have a higher efficiency.

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