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A Review on Use of Solar Energy for Drying

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ABSTRACT: The amount of energy used to dry food items is rising all the time. As a result, solar energy technologies must be considered in order to reduce energy usage. Solar energy is the greatest alternative to other energy sources since it is a clean source of energy. In underdeveloped nations, open sun drying technique is mostly utilized to preserve agricultural goods. In this method, the goods are harmed by insects, dust, rain, dirt, and a variety of other factors. To address these issues, several kinds of solar dryers have been developed and tested, demonstrating that sun dryers are quicker, more effective, sanitary, and better at promoting quality goods than open drying techniques. Solar drying is not feasible at night, which causes the dehydration process to be disrupted. Some integrated or hybrid drying methods have been developed to solve this. Various goods need different temperature ranges for drying, therefore it is critical to dry products at appropriate temperature ranges, which may be accomplished in a solar dryer, in order to preserve product quality and color. A thorough evaluation of several types of sun drying systems for various purposes has been conducted in this communication, assisting in the selection of the appropriate technology depending on the needs.

KEYWORDS: Drying, Industrial, Solar Dryer, Solar Energy, Storage.

1. INTRODUCTION

Due to a lack of adequate storage in most developing nations, a significant proportion of food and grains deteriorate. Because the majority of the water is removed from the product during this process, drying it is an efficient way of prolonging shelf life, enhancing quality, and reducing losses during storage. Drying must be done with hot air that is between 45 and 60 degrees Celsius. Drying food items in a controlled environment of temperature and humidity reduces moisture levels to a safe level while maintaining product quality. To dry various food items, several drying methods are used, including open sun drying, traditional industrial drying using fossil fuels, and solar-based drying systems.

The cheapest way of drying food is open sun drying, however it is susceptible to contamination from dirt and insects, as well as spoiling from unexpected rain. Industrial drying provides excellent drying results, but its expensive cost prevents it from being widely used. The supply of hot air in industrial drying necessitates a large amount of fossil fuels. Solar dryers are a low-cost, solar-powered appliance. During partial clouds and late evening hours, a solar drier without heat storage produces air with significant temperature fluctuations, making food drying impossible. A solar dryer with heat storage is needed in these situations. Solar dryer reliability may be improved by storing surplus energy during peak hours and utilizing it during off-peak hours or when solar energy intensity is sufficient. Solar energy may be stored as sensible heat, latent heat, or a mixture of the two.

Drying energy accounts for a significant percentage of overall energy consumption in developing nations. Fossil fuels, such as coal and natural gas, provide the majority of the energy required for

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drying. To satisfy its industrial, agricultural, and household needs, India consumes about 157 million tons of coal, 89 million tons of petroleum products, and 233 million tons of other typical conventional energy per year [1], [2].

All emerging and developed nations have faced food shortages as a result of population growth, which has resulted in an imbalance in food distribution. Poor storage methods nowadays decrease the quality and amount of food. Farmers, on the other hand, will be unable to expand food production in the face of diminishing land availability to address this issue. As a result, food grain storage through drying is a significant route in terms of food safety and security. Drying energy use is unpredictable, and rising prices and depletion of commercial energy sources have pushed people to turn to renewable energy sources, which are plentiful. Open sun drying was formerly primarily used to dry food grains, fruits, leafy vegetables, and spices. The main benefit of this drying method is that it can store food for a long period, but it also degrades the quality of the food and takes a long time.

Scientists and academics have been working on a solution to this issue for the last several years. They created a variety of solar dryers for different drying applications, and the results showed that the drying process is very easy, inexpensive, and the product is dried in a sanitary atmosphere. Solar drying helps to maintain product quality by decreasing bulk and volume, which aids in better packaging of these goods for better mobility. Open sun drying greenhouse dryers, direct solar dryers, and indirect solar dryers, mixed mode solar dryers, dryers with thermal energy storage, natural convection, and forced convection dryers are among the many types of solar dryer technologies being utilized for drying. Because the product is not excellent under direct sun radiation and better regulated conditions, indirect and tunnel dryers are extremely handy. A variety of factors influence the sun drying process, including solar irradiation and temperature, solar collector performance, and the impact of air velocity, among others [3], [4].

The thermal energy storage device is also utilized in conjunction with a new design solar dryer, which helps to increase the temperature range and drying time. However, this technology raises the initial investment. As a result, although these systems are quite helpful for industrial purposes, they are not very successful when utilized by farmers. Because solar energy is a carbon-free source of energy, every government and productive house in the globe is looking for methods to decrease greenhouse gas emissions in their operations. As a result, they are installing and using renewable energy instead of commercial fuel.

Sun energy is divided into two types those used to generate electricity and those utilized in thermal energy applications, such as solar drying. Solar drying is becoming more popular in the industrial sector for a variety of commodities such as biomass, brick, cement, textile, polymer, paper, and dry fruit, as well as for other purposes such as waste water treatment. The quantity of energy used depends on the product being dried; nevertheless, using a solar dryer reduces the financial load. One drawback of solar drying is that the sun's availability is unpredictably variable, and it is not accessible at night. As a result, hybrid solar dryers include auxiliary electric heaters, thermal energy, biomass, and other alternative energy sources [5], [6].

1.1. Classification Of Different Types Of Solar Dryer

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Solar Dryer has been classified as open sun dryer, direct solar drying, indirect type solar dryer, mixed mode solar dryer as shown in figure 1.

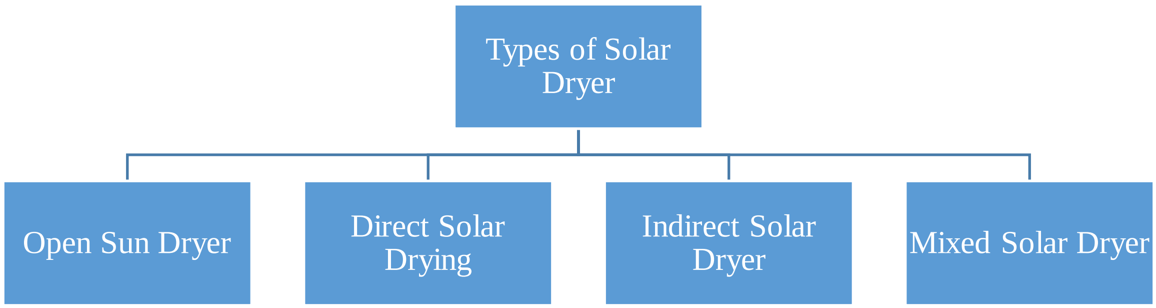

Figure 1: Illustrates the different types of solar dryer used for various porpuses.

1.1.1. Drying in the open sun:

Open sun drying is an old and simple method for drying agricultural products that has been utilized since ancient times. For open sun drying, plastic and metal sheets are utilized, and goods are spread over them directly under the sun's rays. The sun is an uncontrollable energy source that is affected by weather. Most of the sunlight that falls on the surface of a sheet is reflected back, and the quantity of radiation absorbed, which causes temperature to rise, is determined by the color of the crops. Because there is too much heat loss in the open, it is not a viable method of using solar energy. The drawback of deteriorating crop quality and therefore being unable to satisfy food standards. The drying process takes a long period. More restrictions include soil mixing, dust, weather conditions influenced by rain, birds, insects, and the need for a wide area. To address these limitations, researchers devised a much more effective sun drying method. These techniques are more efficient and improve the quality of dried goods as compared to open-air drying [7], [8].

1.1.2. Drying by direct sun radiation:

Direct sunlight drying is a kind of open-air drying that has been modified. This technique uses a transparent plastic sheet or a mirror as a top cover to reduce heat loss to the exterior of the dryer. Simultaneously, it provides protection from insects, birds, dust, and other elements, as well as adequate ventilation for the evacuation of evaporated water from crops. The majority of the air is transported out from the top of the dryer via the aperture, which allows air to enter from below. It shortens the drying time and speeds up the drying process. The box type or cabinet dryer and the greenhouse dryer are two examples of this kind of dryer. A box type direct solar dryer is composed of wood (plywood), mirror, and frame, and is highly insulated with insulation such as rock wool, glass wool, mineral wool, polyurethane, and so on. The mirror is tilted in front to capture the most rays. These dryers may have a natural air flow or a forced air flow utilizing a centrifugal fan.

A new kind of direct solar dryer, called a cabinet dryer, uses sun radiation as a source of energy to dry products. However, despite these significant features, this sun dryer has certain drawbacks, such as darkening of the body and a decrease in nutritious value.

1.1.3. Solar dryer of the indirect type:

To address the drawbacks of a direct solar dryer, a modified kind of drying system, known as an indirect type solar dryer, is utilized. These dryers offer a larger temperature range than direct sun dryers and dry in less time. It is made up of two parts: a flat plate collector and a drying chamber. A metal absorber plate with high heat conductivity, such as copper or aluminum, is used in the collector, which is then covered with a mirror. The air is heated in the collector, and the crops are kept in the drying chamber. Air is allowed to flow into the collector via the intake, where it is heated before being sent to the drying chamber to decrease crop moisture. The moist air is pushed out of the chamber via the exhaust chimney at the top after passing through the crops. These dryers are more efficient than direct sun dryers, and they also protect crops from direct solar radiation. Other benefits of indirect sun drying include a faster drying rate, a smaller footprint than direct solar drying, and the preservation of nutritional content, although the initial cost is considerable. Figure 2 shows the indirect type solar dryer [9], [10].

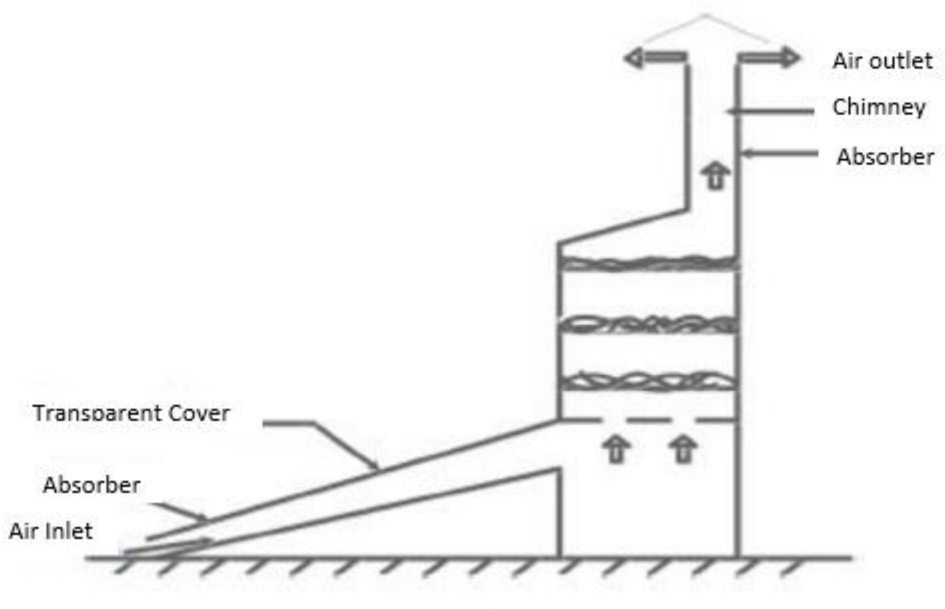

Figure 2: Illustrates the schematic diagram of indirect solar heater.

1.1.4. Solar dryer with mixed mode:

It is a mixture of two types of solar dryers, one direct and the other indirect. This kind of solar dryer raises the temperature to a high level in a short amount of time and is suitable for products with a high moisture content. It may also be used in industrial applications such as textile cement. There are three components to this kind of solar dryer:-

- Air conditioner (with absorber plate optional)
- Chamber for drying
- Chimney

Indirect solar dryer air heaters, for example, absorb solar energy and increase the temperature of incoming air at the base intake. In the drying chamber where the crops are to be dried, hot air is forced upward. Because the drying chamber is based on a direct sun dryer, a transparent sheet is utilized to cover the top. The drying chamber receives sun rays as well, which helps to raise the temperature. The heated air in the drying chamber flowed through the crops before exiting via the chimney at the top. The air heater is positioned at a slant (at latitude or depends on the location).

There are two kinds of mixed mode dryers: the first is a tunnel solar dryer, and the other is a cabinet dryer. These kinds are utilized for a variety of drying applications depending on the temperature range needed for the materials.

2. DISCUSSION

Heat and mass transfer techniques are used in the drying of food and agricultural products. Heat is transmitted to cause liquid in food to evaporate, and mass is transferred as a liquid or vapor inside the solid and as vapor from the surface. Conduction, convection, radiation, or a mix of these methods are used to deliver heat to food. The flow of liquid or moisture inside a solid is determined by the solid's structure and properties. Diffusion, capillary forces, shrinkage, and pressure gradients are the various processes of moisture transport during food drying. During the early stages of drying, the rate of drying is steady. Diffusion of vapor from the saturated surface of the substance through a stagnant air layer into the surroundings is how drying occurs. The size of the constant rate is determined by three factors:

- The coefficient of heat or mass transmission,
- The surface area that has been exposed to the drying medium, and
- The temperature or humidity differential between the gas stream and the solid's moist surface.

The constant rate is unaffected by the underlying mechanism of liquid flow. When the moisture content of the solid reaches critical moisture content, the constant rate drying phase ends. With the passage of time, the rate of drying lowers, and the era of decreasing rates starts. The rate of internal moisture flow now determines the drying rate. The pace of drying is determined by variables that influence moisture diffusion away from the evaporating surface. The amount of energy required for drying is determined by the starting and final moisture content of the food.

The following is an example of a modified solar dryer:

3.1. Solar dryer hybrid:

In addition to solar energy, these dryers are provided with a backup heating supply. These hybrid solar dryers may be used at any time of day or night, as well as in bad weather. This system makes use of auxiliary electric heaters, phase change materials, and biomass backup heating. These systems are often essential when continuous heating is required. The temperature range of hybrid solar dryers is broad, and they are fueled by a secondary source. Trays are provided for loading and unloading the item to be dried.

3.2. Using a v-grooved absorber plate for solar drying:

A black painted absorber plate with a v-grooved form is used in this kind of sun drying to increase the heat transfer surface with air. The dryer's effectiveness improves as air moving from the absorber plate acquires conductive heat from the greater surface area.

3.3. Phase change material (PCM) solar dryers:

The drying time is extended when phase change material is used. Solid-liquid phase transition materials are often used in this application. Solid phase transition materials absorb heat from the sun and change into liquids approaching their melting point. This stored energy is released when the sun isn't shining. It also assists in maintaining the solar dryer's temperature. Paraffin wax is a common PCM in solar dryers.

3.4. The absorber plate's fins are as follows:

Fins are supplied on the absorber plate and are painted black. Fins, which are made of the same material as the absorber plate, are used to enhance heat transfer while using fluid (air). It helps to increase the air temperature for drying while also extending the duration for air inside the collector.

It has been shown that solar drying of food may be done at night or during non-sunny hours utilizing a solar dryer with a heat storage system. From a technological and energy-saving standpoint, sun drying for food and agricultural goods has a lot of promise. Over the past several decades, researchers have employed a variety of materials as storage materials in sun dryers, including rock, water, sand, and granite, metal scrap, pure paraffin wax, and a combination of aluminum power and paraffin wax. The majority of sun dryers utilized SHS materials like pebbles and oil. There is very little information on the usage of LHS materials in sun dryers. When space constraints prevent bigger thermal storage units from being utilized in sun drying systems, latent heat may be utilised. Because of its cheap cost and ease of availability, paraffin wax has been utilized as a heat storage medium in most prior research studies; nevertheless, paraffin has a poor thermal conductivity. This disadvantage may be mitigated by artificially enhancing thermal conductivity, such as by injecting a high thermal conductivity metal matrix and adding fins to the heat transfer surface. A PCM with high latent heat and a wide surface area is needed for excellent thermal performance of a solar air heater. A small, high-efficiency, long-life, and cost-effective solar dryer with a heat storage system is required. To decrease the overall cost, volume, and heat loss, further research on solar energy collecting and thermal storage is needed.

3. CONCLUSION

This article provides an overview of advances in several kinds of solar dryers, including direct, indirect, mixed mode, and solar dryer advancements. Solar dryers have been determined to be the greatest choice for replacing traditional energy-based drying techniques, according to the research. Mixed mode solar dryer technology, out of all the existing techniques, has been proven to be superior in terms of produced output if correctly constructed. Solar drying methods are also found to have limited use in the industrial sector as compared to agriculture. To make these equipment's more cheap for farmers, additional work has to be done on the design and manufacturing elements.

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