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Research Article

Across-the-board over-view of solar dryers; an extensive scale renewable energy consideration for drying agricultural products

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Abstract – The agricultural product drying is a time-consuming and energy demanding practice. However, un-economical, and depletion of fossil fuels as well as environmental jeopardies fascinate the utilization of solar-energy as substitute source, predominantly in the emergent countries. Escalating environmental concerns prompted the use of renewable energy resources (RER's) in the drying ofagricultural foodstuffs. As a consequence, the solar-dryer (SD) is a reasonably effective approach for drying agricultural products in a highly uniform manner. However, over the last few decades, a considerable several researches have been established for the purpose of drying food and agriculture products using a SD. This review paper focuses on the substantial achievements devoted to the development of solar drying technology available today, as well as the state-of-the-art developments in solar drying. Furthermore, the comparison of advantages/disadvantages of In-direct type solar dryers ***(***ITSDs) is also the part of this paper.

Keywords –Open sun drying, Renewable energy application, Solar Energy, Solar dryer

I. Introduction

Although drying system (DS) and thus preserving horticultural and agricultural harvests is among the oldest applications of solar energy, its enormous potential in the food processing industries has not been fully explored scientifically [1-3]. Practically, most important methods for preserving vegetables and fruits is the drying. In addition, drying is also the oldest method of removing water from a variety of materials, including wood pulp for papermaking, building materials, and food preservation [4].

Despite the fact that drying energy originatesfrom a wide variety of sources, notably fossil resources, natural gas, biomass, electricity, and solar, the subject of this study review tends to fall under the implemented sources such as solar. In thedeveloped world, these methods of thermal drying account 10–20 precent of total industrial energy consumption. Hydrocarbons cause pollution, and that there is no guarantee that they will always be available [5]. Solar energy is a cost-effective and efficient source of long-term strategies for sustainable growth. The earth gets a huge amount of solar energy. It is advisable to replace the traditional process of drying with available sun energy in order to preserve fruits and vegetablesfor a long period of time. Often these agricultural products have high moisture levels once harvested, which causes deterioration due to bacteria and fungi growth. Maintaining agricultural products at safe moisture content eliminates the risk of spoilage under normal conditions [6-8].

Numerous approaches for food preservation for later usages are already in use.

The traditional method of food preservation is drying. Due to the obvious loss of moisture, the weight and size of the product are reduced, making storage and transportation easier. Drying prevents fungi and bacteria from germinating and growing. For different foodstuffs, there are suggested drying the moisture content, and for storing them longer [9]. The main goal of a drying process is to provide heat in the most efficient way possible in order to produce the highest quality product with the least amount of energy expenditure [10-15]. Air-dryers, which utilized a lot of fossil-fuel, are used in traditional drying techniques. However, rising prices, a scarcity of fossil fuels, and growing environmental concerns put a premium on the use of RER's, such as solar energy, as an alternative source of energy in emerging nations [16]. Heating air electrically for drying is one alternative; however, it is costly and in some cases impractical in rural areas of developing countries. In both urban and rural areas, the use of RER's to encounter energy demand in an environmentally sustainable system has become unavoidable. In the domestic, commercial, and industrial sectors, drying systems based on RER's have been successfully established. Solar systems have theability to fulfill the growing need for energy. Hence, this energy could be put to good use in drying agricultural crops [17-19].

The body of the paper is composed as follows: section II describes the various types of solar Dryers. Comparison of advantages/disadvantagesof various ITSDs is explained in section III. Furthermore, the paper is concluded and also the future scope is presented in section VI.

II. Different Types of Solar Dryers

The DS is divided into two categories based on how much solar energy is used: One among them is controlled solar drying (CSD).

i. Meanwhile, other one is open sun drying (OSD).

However, the classification flow chart in **Figure 1** depicts various types of solar dryers in detail.

A. *Open sun drying*

Open sun drying– The items to be dried are scattered out on the ground or in thin layers on trays, mats, and concrete floors, exposing the product to open air and sunlight.

Rack type - The moist food products to be dried is kept in series or parallel racks in this method. Controlling drying parameters such as humidity, velocity, and temperature is challenging in bothopen and rack types. It has a number of benefits; including high-quality products, a shorter drying time, dust-free, and large-scale production [20].

B. *Controlled solar drying*

Is from the other hand, revolutionary new dryers with controllable drying parameters are available in the literature. Food quality is affected by the working fluid temperature, humidity, velocity, and other factors during solar drying of agricultural goods [14], and [18]. Various methods can be used to control these influencing

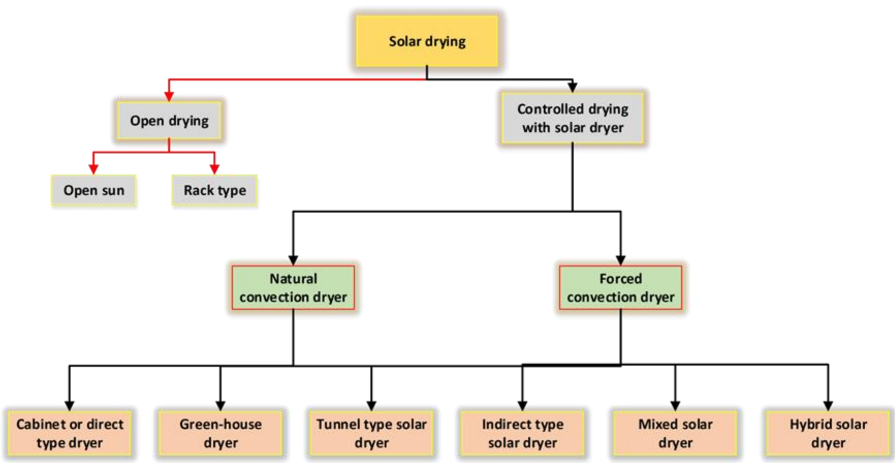

Figure 1. Different Types of Solar Dryers.

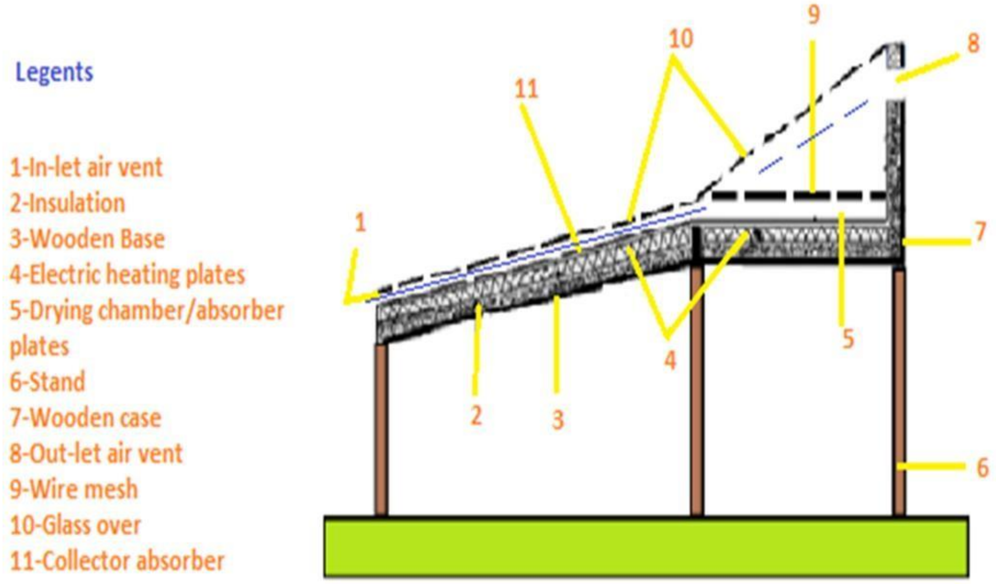

Figure 2. A Schematic view natural convection ISD setup[25]

parameters. In addition, in controlled solar drying, solar energy can be kept in the forms of heat. The following are the different kinds of solar drying systems that can be controlled:

1. *Direct solar dryer*

In the direct solar dryer (DSD), transparent glasses are used to impart radiation from the sun straightforwardly to the food stuffs [15]. Losses of Convective must be lessened in these dryers, allowing the drying compartment temperature to be enhanced. Glass-roof solar/ solar cabinet dryer [21] and green-house dryer [17] are examples of direct solar dryers.

2. *Indirect solar dryer*

The literature identifies two types of ISD: (a) Natural convective type and (b) forced circulation type 18].

2.1. Natural convection ISD –

Many ISD experiments have been carried out with a simple flat plate and dehumidifier. Without the need of external equipment such as fans or blowers, air is naturally circulated. A fan's cost and upkeep are reduced by convection. A studyof certain ISD with collector and single pass flat plat collector is included in this part, as well as an explanation of the results obtained during natural convection ISD drying. In Jaipur, India, Parikh and Agrawal [22] conducted experiments and analyzed the cabinet dryer with two shelves and aflat plate collector. Green chilli and potato (S. tuberosum) chips were investigated. To improve dryer efficiency, glass and polycarbonate sheets were used as glazing covers. With glass glazing as a cover sheet, the efficiency increased from 9–12% to 23.7 percent, and 18.5 percent with polycarbonate sheet. As a result, the drying time was drastically reduced. **Figure 2.** Depicts a schematic overview of natural convection ISD setup.

2.2 Forced convection setup ISD –

The air is forced into or out of the dryer using an electric fan or blower. As a result, in this type of dryer, you can control the drying rate. It's classified similarly to natural circulation, but with the accumulation of a fan/blower [25]. Solar dryers with greenhouse collectors and tunnel typedryers with integral collectors are two other types of solar dryers [22], [24**]. Figure 3** shows a

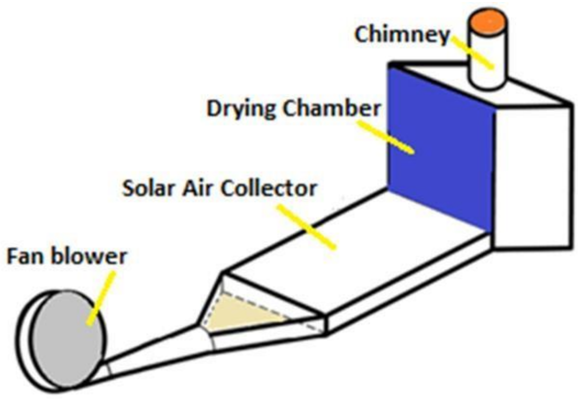

Figure 3. Forced convection ISD

Table 1. Different types of ITSDs with their advantages and disadvantages[22]. [24].

Types	Sub-types	Advantages	Dis-advantages
Natural Convection ITSD		Simple in design and easy to fabricate. No commercial energy required. Fabrication, operational and maintenance costs are low. It is used for the materials with low temperature requirement.	Low efficiency compared to other types of ITSD. There is no control over the temperature and velocity of flowing air; hence difficult to control the drying rate. Not useful for material which requires high drying temperature.
Forced convection setup ITSD	Forced convection ITSD with single pass SAC	Simple in design and easy to fabricate. Fabrication and maintenances costs are less. Control over the drying is possible by controlling the flow rate of air with the help of fan or blower. Drying is possible with and without fan.	Low efficiency and low temperature compared to multi pass ITSD. Needs electric power for fan or blower.
	Forced convection ITSD with multi-pass SAC	Fabrication and maintenance costs are more compared to natural ITSD. Controlling the drying rate is possible	Complex in design and structure. It cannot work without fan or blower, so needs continuous electric power.

forced convection type indirect solar dryer setup.

III. DISCUSSION

In this paper, **Table 1** lists the advantages/disadvantages of various ISD's. When compared to OSD drying, all ISD's have the same feature: the products are protected from direct ultra-violet radiation.

IV. CONCLUSION

Agricultural product drying is an energy-intensive process. Solar energy as an alternative source is becoming more popular, especially in developing countries, due to high costs, scarcity of fossil fuels, and environmental threats. This review paper focuses on the significant contributions made so far in the field of solar drying systems, as well as the most recent advancements in the drying technology.

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