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Literature Review on Solar Food Dryers

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Synopsis: Food preservation by drying is one of the most important processes of packing and storing foods and fruits, which in turn requires the use of industrial mechanical techniques that require exposing food products to thermal energy. The heat needed to dry fruits and foods comes from two main sources: fossil fuels and solar radiation energy. In the past, foods and fruits were dried in the traditional way, either in ovens powered by fossil fuels or coal or by exposing fruits and foods directly to sunlight. Hence, the old traditional methods are characterized by many disadvantages. For example, the use of drying ovens that rely on fuel energy causes environmental damage and requires financial costs, while the method that relies on spreading the crop under direct sunlight is vulnerable to fluctuations in weather conditions such as humidity and pollutants in the air. Now, in light of the presence of many challenges such as climate change, global warming, increased demand for fossil fuels, the accumulation of pollutants resulting from the use of oil, the continuous rise in fuel prices, the concentration of fossil fuel sources in fragile security regions such as Russia, Ukraine, the Middle East, and North Africa, and weak infrastructure in many developing countries, all of this and more makes it necessary to use solar energy in the process of preserving and drying foods and fruits because it is widely available in most regions and is safe in addition to being environmentally friendly. Some solar dryers can operate at full capacity without the need for an additional energy source such as electricity or fuel [1–4]. This paper provides an overview of the benefits and limitations of using solar dryers, the most important types of solar dryers currently used, the most common, and how each of them works. This study was reinforced by referring to many previous studies of various designs that were able to enhance the efficiency and productivity of solar dryers in their various forms. To reach the best possible design for each specific type of fruit with the highest productivity and the lowest cost.
Keywords: Solar dryer, Renewable energy, Food dehydrator, Environmentally friendly applications, Solar dryer kinds

I. Introduction

With the large population growth and rapid increase in the population of various countries around the world, most countries suffer from a clear food shortage, so it has become required and necessary to create a population nutritional balance. Due to inadequate processing techniques and storage facilities, there has been a decline in the quantity and quality of grains that have been stored. It is necessary to establish a population-food balance to reconcile the rate of population growth with the amount of food they need [5]. It is extremely difficult to make optimal use of the products of small farmers. To solve these problems, drying processes had to take on an advanced form to be the most important primary methods used to preserve food in areas where solar radiation is available. Many researchers have worked to develop and solve many of the problems and defects that characterize traditional solar drying [5]. With the availability of free solar radiation in different regions of the world, many researchers have worked to develop many important applications in the field of solar energy, including solar stills, air convectors, water heaters, food cookers, and agricultural product drying devices [6-10].Many farmers work to preserve agricultural products and seeds by using drying systems that use solar energy as a source of heat, which is considered practically appropriate, has low costs, and has high performance. Heat is applied to the surface of the object at a constant rate during the first step of the drying process. Reducing the drying rate is what is included in the second stage [11]. It is possible to rely heavily on the solar dryer to dry fruits and grains and reduce storage damage losses. The closed solar dryer has features and characteristics that make it superior in performance and productivity to the open solar dryer. For example, the quality, cleanliness, and shape of the agricultural product can be preserved to a greater extent using closed drying compared to open drying. To dry crops and other agricultural products, many farmers utilize sun dryers with a variety of forms, sizes, and engineering designs. As a result, it can be said that choosing the appropriate type and design of the solar dryer to do this task is very necessary, as many studies have been presented to manufacture the appropriate solar dryer for the required task with the highest efficiency and the lowest cost [12]. It is certain to say here that solar energy is the most reliable source in terms of cleanliness and non-production of pollutants, and that it can be a source of electricity or a source of heat in various applications such as drying and others [13]. The solar dryer can be classified into two types: direct solar dryers and indirect solar dryers, depending on the method of producing thermal energy and the number of connected units that make up the solar dryer. Barnwal and Tiwari[14] presented a study that included the use of a direct-type drying device with a capacity of 100 kg, and the device was tested to dry Thompson seedless grapes, as shown in Figure 1. As for the indirect type, it consists of a group of parts connected to each other, such as the air collector, solar energy absorption panel, air blowing fan, and drying container, which in turn work with each other to form the solar drying device [15], as shown in Figure 2. It can be noted that indirect solar drying collectors are more efficient than direct solar collectors.

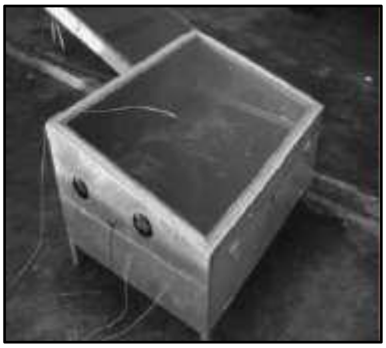
Fig.1: Direct-type dryer [14].

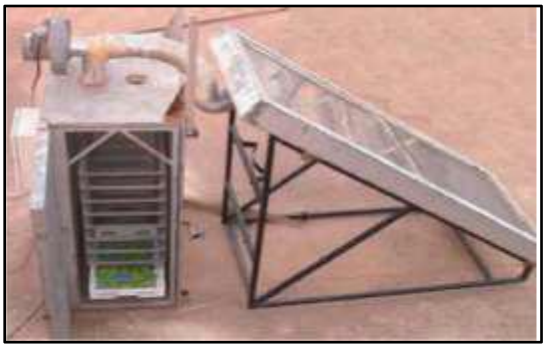
Fig.2: Indirect-type dryer [15].

II. Solar Drying Equipment Benefits[16,17]:

1- A way to store agricultural products with excellent quality.
2- It reduces damage to food crops, which helps maintain their price for the consumer.
3- The solar dryer is able to protect the agricultural product that is inside it from weather changes such as rain and humidity, as it is completely covered.
4- Environmentally friendly and pollutant-free, not dependent on fossil fuel energy.
5- Low cost and does not require experience to operate.

III. Limitations of Using a Solar Dryer:

1- Not suitable for some agricultural products due to the decrease in product quality after the drying process.
2- It works effectively in areas characterized by high amounts of solar radiation.
3- It requires a longer drying time compared to equipment operating on fossil fuels.

IV. Literature

Solar dryers are available in different shapes, sizes, and designs, depending on the required function. Based on this, it can be said that solar dryers can be classified mainly based on the drying temperature, so they are divided into two types: high-temperature dryers and low-temperature dryers. The solar dryer can be classified based on the following set of criteria:

1- Mode and direction of air movement.
2- Exposure to insulation.
3- Configuration of the dryer.
4- Percentage of dependence on solar energy.
5- The type and quantity of agricultural product to be dried.

V. Solar dryer kinds:

1- Open Sun Drying:-

In areas characterized by high solar energy intensity, farmers distribute their fruit products in a thin layer on trays in a way that exposes them to sunlight and air flow, which dries them. Here, we can classify solar drying techniques based on the number of processing stages, drying location, and sensitivity to sunlight [18]. It should be noted here that the open drying method is not suitable for large quantities because it requires more labor and requires large areas full of solar radiation, in addition to the low quality of the product [19]. To prevent losses resulting from open drying, such as losses resulting from rain, humidity, wind movement, or animal obstruction, closed drying is usually used. In addition, incomplete drying causes many problems, especially after the storage process, which makes the stored products vulnerable to many fungi and a suitable breeding ground for mold growth [20].

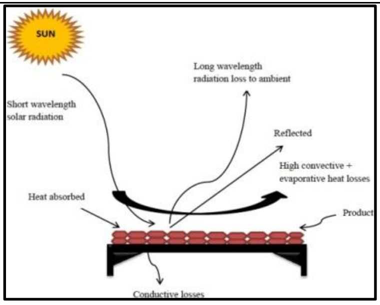

Fig.3 Open Sun Drying [24].

2- Direct Solar Dryer

It is the method of using sun radiation that strikes the fruits directly, absorbing them and drying them out as a result. Here, it can be concluded that this kind is distinguished by a decline in the product's quality brought on by exposure to direct sun radiation. The drying apparatus is made up of a closed chamber that holds the product and a transparent upper surface that lets light from the sun pass through. Rising air forces remove the steam generated during the drying process [21]. Direct solar dryers are used in many regions around the world that have long solar days [22]. A direct-type solar dryer was installed, made of a 1cm-thick wooden bed insulated with glass wool on all sides and covered with a transparent glass layer. Steam is expelled through vents equipped with a fan placed at the back [23].

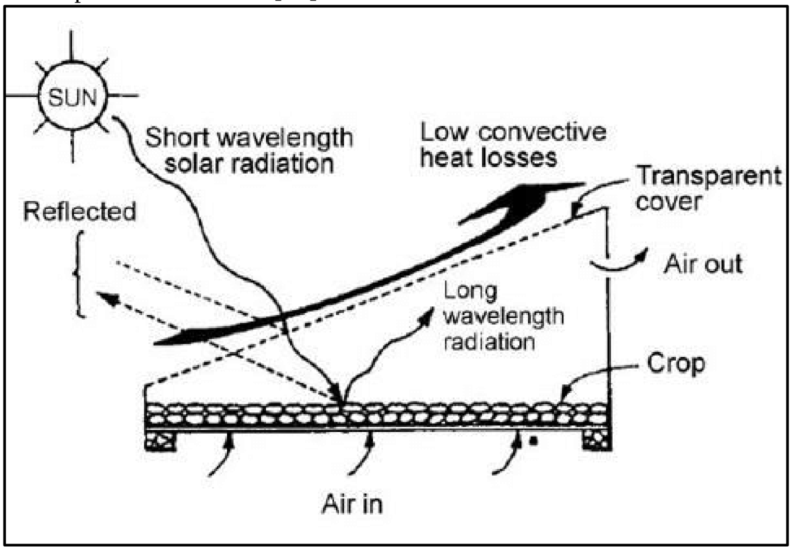

Fig.4 Direct solar dryer [23]

3- Indirect Solar Dryer

In this method, the solar dryer is divided into two halves. The first half is a solar collector that receives direct solar radiation through an absorbing part that, in turn, heats the air passing through it. The next part is a closed room that contains the agricultural product and through which hot air passes that works to dry the fruit. In this type, the quality of the product is increased, and the best possible solar drying process is achieved.Bhardwaj, A.K., and others [25] They were able to present a useful study that involved the creation and application of an indirect solar fruit dryer that employs phase-change materials for heat storage. As seen in Figure 5, this allowed for a 64.29% reduction in the amount of time needed to dry fruit when compared to a traditional dryer.

Fig.5 Indirect Solar dryer [25]

4- Mixed Mode Solar Dryer:

This type of solar dryer combines the previous two types. It consists of two separate parts: the solar radiation collecting plate and the drying chamber, but here the drying chamber has a transparent surface that allows solar radiation to enter to increase the amount of thermal energy received [26]. Through a comparative study between this type and the two previously mentioned types, it was found that using this technology has more satisfactory results in terms of drying effectiveness and moisture content. The result of using mixed drying showed that the highest efficiency was 21.24%, with a final moisture content of no more than 13% [20].Senay Teshome Sileshi et al. [27] presented a numerical study that involved the use of a mixed-mode solar dryer consisting of three parts: a black plate to collect solar radiation, a vertical duct to transport hot air, and a drying chamber containing four trays arranged in a row. The ceiling of the drying room and the surface of the solar collector panel were covered with transparent material. The results obtained showed that the use of the vertical distribution channel enhanced the chances of homogeneous distribution of dry air on the trays, which led to an increase in dryer productivity as the percentage humidity difference between the trays did not exceed 2%, as shown in figure 6.

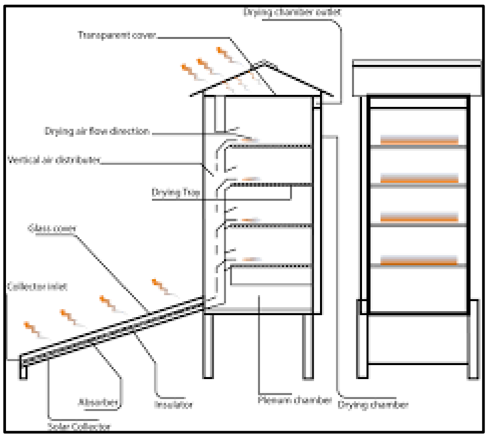

Fig. 6 Mixed Mode Solar Dryer [27]

5- Natural convection solar dryer

The natural convection solar dryer plays an effective role in drying and preserving foodstuffs due to its low cost. Because it regulates the temperature without the need for an external power source. Moreover, its high popularity stems from its ease of maintenance and the lack of need for an experienced operator. It is an excellent method for drying lightweight grains that can blow away when using a forced air source, such as raw rice. O. Kilanko et al. [28] studied an indirect solar dryer with natural convection containing 200 grams of Scotch bonnet pepper inside a drying chamber. The study lasted for three weeks, and statistical graphical analysis was used to determine the loss of mass and moisture during each day, as shown in figure 7.

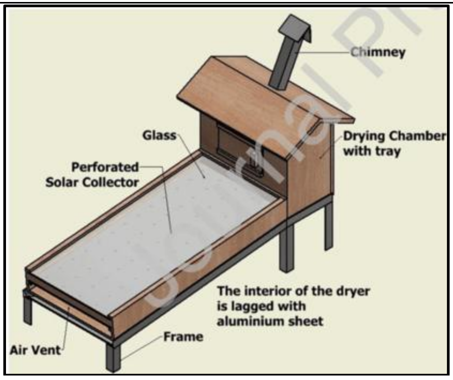

Fig.7 Natural convection solar dryer [28]

6- Greenhouse solar dryers:

An integrated solar complex in which a group of successive solar processes are produced throughout the year, such as planting, treating, and drying plants. Through a numerical simulation study, Huang and Toksoy [29] were able to track the growth of tobacco seedlings and the suitability of the climate for them, as these seedlings achieved significant growth and production.In this method, heat and mass transfer are applied simultaneously during the drying process. In this system, solar radiation enters through the cladding material, which increases the temperature of the fruits equally. The following figure shows a schematic model of greenhouse solar dryers.

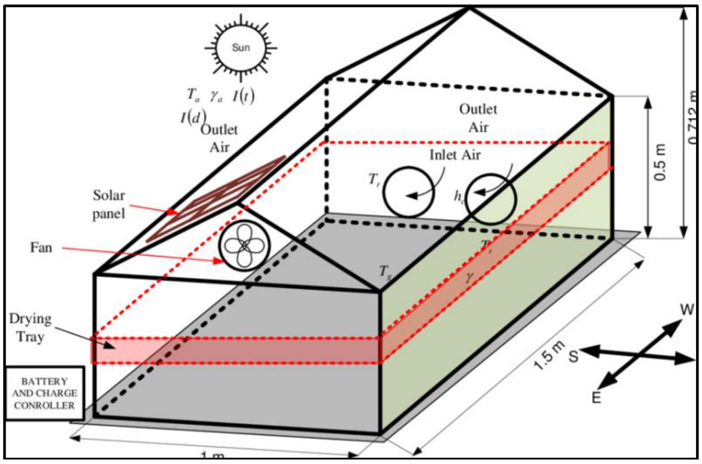

Fig.8 Greenhouse solar dryers [29]

7- Hot Box Dryer:

This type consists of an insulated wooden box containing a dark-colored absorption board with holes separated from the base of the box by an air cavity called a drying cabinet. The upper surface of the box is covered with a layer of transparent material. The temperature of the opaque absorbent panel rises as a result of it absorbing solar radiation that passes through the transparent part, which leads to an increase in the temperature of the internal air in the box. Hot air leaks down through the vents, creating a partial vacuum, which causes cold air to rise to the top, dehydrating the fruits in the drying cabinet, as shown in figure 9 [30, 31].

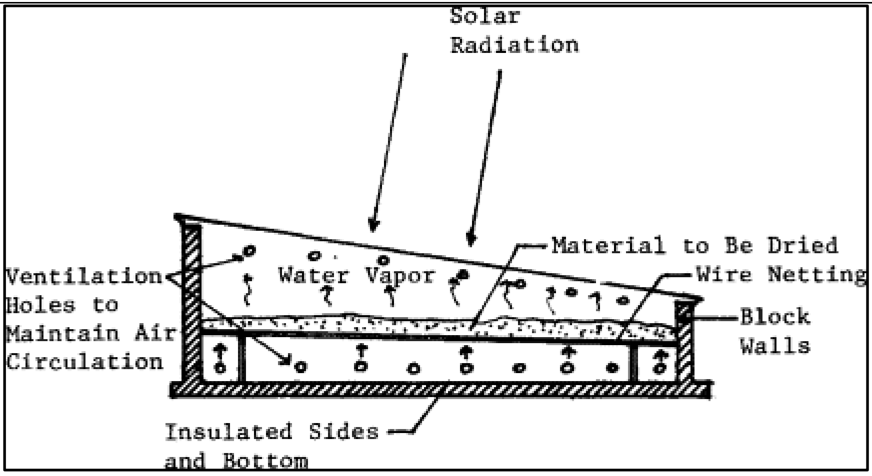

Fig. 9 Hot Box Dryer [31]

8- Tunnel type solar dryers:

A practical study was presented by Rathore and Panwar [32] to test a hemi cylindrical solar tunnel dryer, which is used to dry seedless grapes of the Sonaka type. The results showed that this type of fruit needs one week at a temperature ranging between 10 and 28°C to be completely dry, as shown in figure 10.

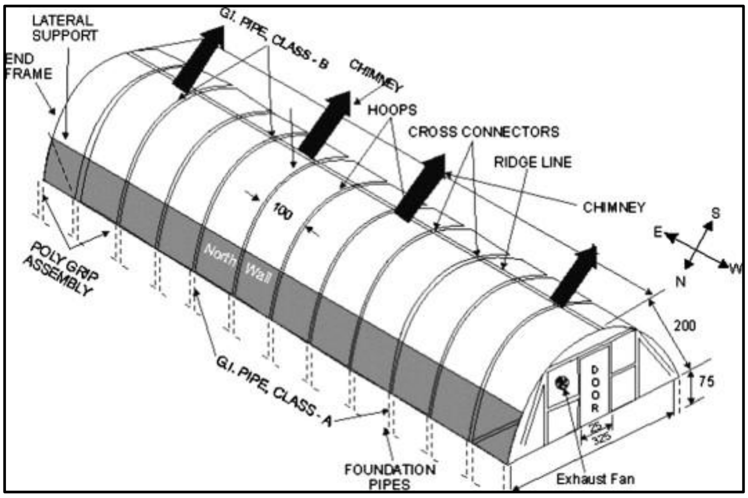

Fig.10 Tunnel type solar dryers [32]

9- Solar chimney dryer:

It is a solar drying system used to dry agricultural products and fruits. The operation of this type of solar dryer is affected by the amount of humidity, air velocity levels, and temperature as a function of available solar radiation [33-35]. The experimental thermal study presented by Fawzi Nasri [34] included the use of a chimney-type solar dryer, which consists of an absorption plate, a glass cover, and a chimney. While the model was experimentally tested at different air flow rates for drying bananas and peaches, the results achieved were highlighted graphically, as shown in figure 11.

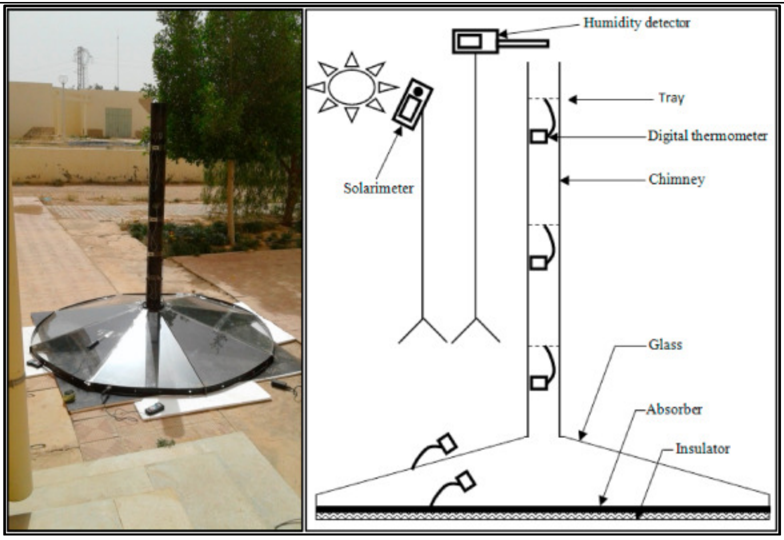

Fig. 11 Solar chimney dryer [34]

VI. Conclusion

This literature review paper includes the most prominent and important designs of different types of solar dryers that are not expensive, how to install each of them, and the application of each of them. Direct and indirect solar dryers, as well as active and passive dryers, were reviewed, while the review focused on the most important types that can produce high-quality dried products. In addition, open solar drying and its treatment methods were discussed. The most important advantages and limitations of using solar drying in general were also discussed.

Below are the most important things that were reviewed during this research paper:

a- An overview of the use of solar dryers in developing countries and countries with high solar density.
b- Highlight the different designs and the importance and nature of their use and installation.
c- Solar drying, which relies on heat storage and can extend the drying period in the period when solar radiation is not available, has also been mentioned.
d- The importance and benefit of using the solar dryer were discussed, as it is the most important means of preserving fruits, is an environmentally friendly method, and does not require operational costs.
e- The most important determinants of using solar drying were mentioned.

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