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A Review on Various Types of Solar Dryers and their Applications

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Abstract: *Solar Drying is one such ancient technique of food preservation. Drying is an essential process in the preservation of agricultural crops and in Industries. Drying is a method of removing the moisture from the product up to its safe moisture limit. The different types of solar dryers, and method are tabulated in the paper separately. Further, the paper also covers the application of dryers in different sectors. Solar dryer enhances the food usefulness, storage capacity, protection from environment effects & reduces the cost of transportation.*

Keywords: Solar Drying, direct dryer, indirect dryer, Food preservation, Industries, environment

I. INTRODUCTION

Drying is one of the methods used to preserve food products for longer periods. The heat from the sun coupled with the wind has been used to dry food for preservation for several years. Drying is the oldest preservation technique of agricultural products and it is an energy intensive process. High prices and shortages of fossil fuels have increased the emphasis on using alternative renewable energy resources. Drying of agricultural products using renewable energy such as solar energy is environmental friendly and has less environmental impact.

There are several ways of preserving food for later use. Drying is a traditional method for preserving food. It also helps in easy transport since the dried food becomes lighter because of moisture loss. Drying of seeds prevents germination and growth of fungi and bacteria. The traditional age old practice of drying food crops inn developing countries is, spreading food products in open sun which may be termed as open sun drying or natural sun drying. In this technique the product is spread in thin layers on a hard platform and the product is turned once or twice a day. This natural sun drying is simple and economical.

There are three basic methods of drying (1) in storage layer drying (2) batch drying, and (3) continuous flow drying. The fuel used in controlled drying of food is generally electricity, oil, natural gas or coal. If a little technology and money is applied then solar energy can be a possible solution for the dehydration of food. Experiments conducted in many countries have clearly shown that solar dryers can be effectively used for drying food. It is a question of adapting it and designing the right type of solar dryer for a particular product. Solar energy is all the more effective for food drying because of following reason:

(a) Solar energy is diffuse in nature and provides low grade heat. This characteristic of solar energy is good for drying at low temperature, high flow rates with low temperature rise.

(b) The intermittent nature of solar radiation will not effect the drying performance at low temperature. Even the energy stored in the product itself will help in removing excess moisture during the period of no sun shine.

(c) Solar energy is available at the site of use and saves transportation cost.

(d) The high capital cost of solar dryers can be compensated if the dryer is used for drying other products also or at least is put to other multiple uses such as space heating, etc.

A review of solar crop drying is given byGarg and Sodha et.al.

II. CLASSIFICATION

Solar drying is generally classified into two categories namely open or natural sun drying and closed sun drying. All the types of solar dryers operate in two modes only i.e. active and passive mode.

In active mode, the crop is dried with the help of forced circulation generated by a fan or blower operated by electrical energy. This requirement is fulfilled either by the PV module or grid energy.

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In passive mode, air flows through the crop by buoyancy force and with the help of wind pressure. The heated air moves in an upward direction due to the thermosyphon effect and it is exhausted through the roof of the greenhouse or the ventilation.

Fig. 1- Drying-of-crops-in-passive-greenhouse-and-the-open-sun-Jain-and- Tiwari-2004

Fig. 2- Setup-of greenhouse-dryer-operating-under-active-mode-Barnwal-and- Tiwari-2008

Passive dryers are suitable for low moisture content crops and less quantity while for high moisture content crops and large quantity, active dryers are
preferred, As for drying a larger quantity of crop, the quantity and velocity of air should be sufficient to carry the moisture evaporated from the crop surface.
Also, passive dryers are cheaper than active ones due to no external devices like fans, PV panels, blowers, etc.

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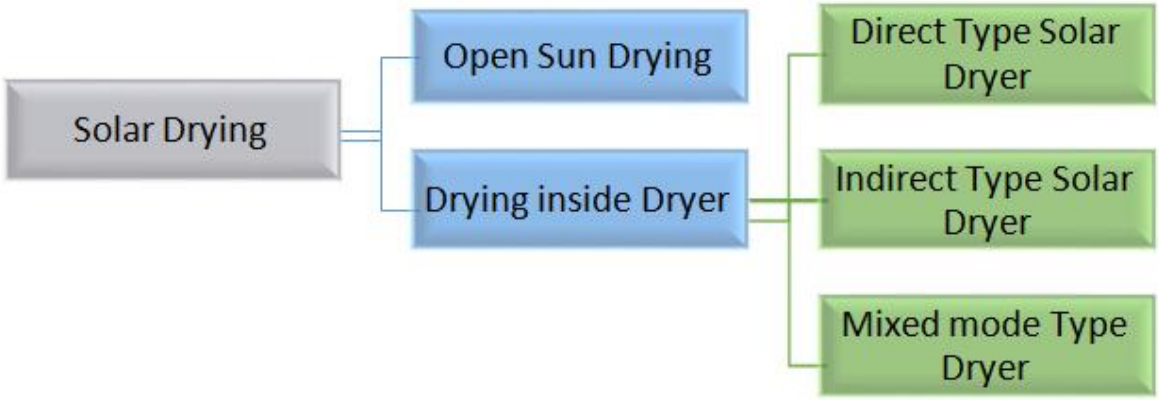


Types of solar dryers

Solar-energy drying systems are classified primarily according to their heating modes and the manner in which the solar heat is utilized. In broad terms; they can be classified into two major groups, namely

• Direct (integral) type solar dryers.

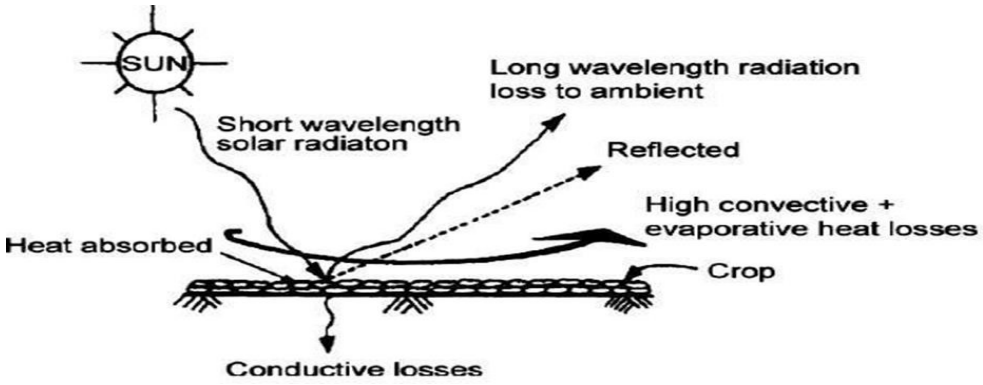
• Indirect (distributed) type solar dryers.

The three modes of drying are: (i) open sun, (ii) direct and (iii) indirect in the presence of solar energy. The working principle of these modes mainly depends upon the method of solar-energy collection and its conversion to useful thermal energy.

Open sun drying (OSD)

The principle of open sun drying is shown in Figure. The product to be dried is spread on a surface. The solar radiation falls on the surface of the product. A part of the solar radiations is reflected back, while the remaining part is absorbed by the surface of the product. The absorbed radiation is converted into the thermal energy and the temperature of the products starts increasing.

Figure 3 shows the working principle of open sun drying by using solar energy.



This leads to the loss of thermal energy in the form of long wave radiations from the surface of the products to ambient air through the moist air.

Simultaneously, there is convective heat loss due to blowing wind over the product. These result in evaporation of moisture and its loss to the surrounding atmosphere and thus product gets dried.

When this process is going on, a part of thermal energy is absorbed by the products and is conducted into the interior of the product. The temperature of water present inside the products rises and results in the formation of water vapour inside the products. These water vapours diffuse towards the surface of the products and finally lost in the atmosphere. The drying rate in the initial

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stages is fast because of the availability of moisture at the surface of the products. Thereafter, drying depends upon the rate, at which the moisture present within the products moves towards the surface. This depends on the type of the products to be dried.

So, you can summarise the entire drying process as follows :

• Product to be dried is spread on a clean surface.
• Solar radiation falls on the surface of the product.
• A part of the solar radiation is reflected back, while the remaining part is absorbed by the surface of the products.
• The absorbed radiation is converted into the thermal energy and the temperature of the product starts rising.
• This leads to the loss of long wave radiations from the surface of the products to ambient air through the moist air. Simultaneously, there is convective heat loss due to blowing wind over the product.
• It results in evaporation of moisture and its loss to the surrounding air and the product gets dried.

Open sun drying, though it is very economical, has many demerits. Some of them are given below :

• Open sun drying requires presence of somebody at site throughout the drying period, so that the products could be protected from
birds,animals and adverse weather conditions.
• The resulting dried products are not of high quality because of dusts and other sediments present in the atmosphere etc.
• The products are usually unhygienic.

Direct type solar drying

Direct solar dryers have the material to be dried placed in an enclosure, with a transparent cover on it. Heat is generated by absorption of solar radiation on the product itself as well as on the internal surfaces of the drying chamber.

Direct solar drying is also called natural convection cabinet dryer. Direct solar dryers use only the natural movement of heated air. A part of incidence
solar radiation on the glass cover is reflected back to atmosphere and remaining is transmitted inside cabin dryer. . A direct solar dryer is one in which the
material is directly exposed to the sun‘s rays. This dryer comprises of a drying chamber that is covered by a transparent cover made of glass or plastic. The
drying chamber is usually a shallow, insulated box with air-holes in it to allow air to enter and exit the box.

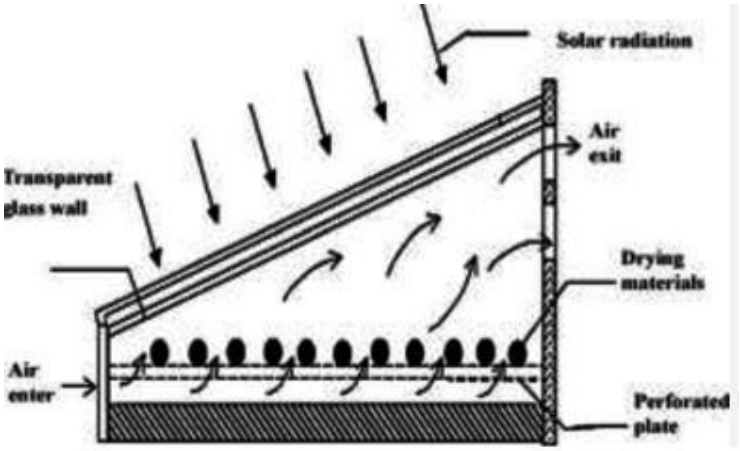

Fig.4: Direct Type Solar Drying

These dryers appear to be more attractive for use in developing countries since these do not use fan or blower to be operated by electrical energy.

Moreover, they are low in cost and easy to operate. However, the problems with these dryers are : slow drying, not much control on temperature and humidity, small quantities can be dried, and some products change colour and flavour due to direct exposure to sun. In its simplest form, they consist of some kind of enclosure and a transparent cover. The

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food products gets heated due to direct absorption of heat or due to high temperature in the enclosure and therefore, moisture from the product evaporates and goes out by the natural circulation of air. There are several design of direct type dryers and these are developed keeping in mind either the availability of local materials required for its fabrication or for drying a particular product. Several dryers are fabricated, tested, and analysed in many countries.

Indirect solar dryer (ISD)

Indirect solar dryer (ISD) is a conventional device. It is essentially composed of a solar air collector (SAC) its role is heating air fluid for removing moisture from product, and a drying chamber where products were disposed. This type is not directly exposed to solar radiation to minimize discolorations and cracking. The drying chamber is used for keeping the in wire mesh tray. A downward facing absorber is fixed below the drying chamber at a sufficient distance from the bottom of the drying chamber. A cylindrical reflector is placed under the absorber fitted with the glass cover on its aperture to minimize convective heat losses from the absorber.

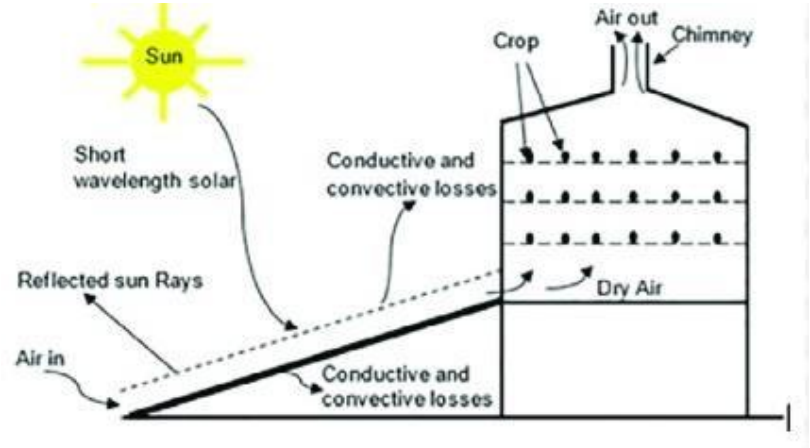

Fig. 5: Indirect type solar dryer

The absorber can be selectively coated. The inclination of the glass cover is taken as 45o from horizontal to receive maximum radiation. The area of absorber and glass cover are taken equal to the area of bottom of drying chamber. Solar radiation after passing through the glass cover is reflected by cylindrical reflector toward an
absorber. After absorber, a part of this is lost to ambient through a glass cover and remaining is transferred to the flowing air above it by convection. The flowing air is thus heated and passes through the placed in the drying chamber. The exhaust air and moisture is removed through a vent provided at the top of drying chamber.

Mixed mode solar dryer

Mixed mode solar is basically a combination of direct and indirect solar dryers. In mixed mode solar dryer, the food is dried by the heat generated from direct sunlight and the heated air from the solar collector. In comparison with direct and indirect dryers, it is best and significantly gives better results. In the mixed mode type of dryers, the solar air heater without any fan along with the drying bin used. The flow of air is generally by natural convection.

This dryer named as ‘rice-dryer’ was developed by Exell in Bangkok, Thailand and consists of a simple air heater, drying chamber, and a tall chimney used to increase the convection effect. The dryer as shown schematically in fig. consists of solar air heater made of a frame of bamboo poles and wire covered with 0.15 mm thick transparent PVC sheet. The ground is covered with burnt rice husk which absorbs the solar radiation and heats the air in contact. The hot air in this air heater rises to the drying chamber which either consists of transparent PVC sheets on bamboo frame absorbing directly the solar radiation or a bamboo frame covered from all the four
sides with some opaque material.

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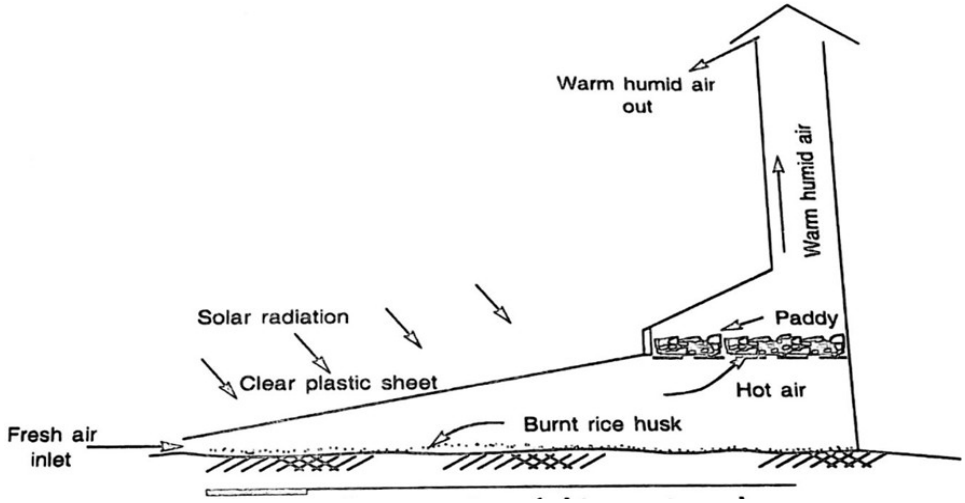

Fig.5 : Cross section of chimney type dryer

The drying material is kept on the nylon net tray in thin layer through which hot air heated from air heaters enters its bottomand goes up in to the chimney. The chimney is a long cylinder made of bamboo frame covered with black PVC to keep the inside air warm. There is a cap at the top of the chimney, leaving some space in between chimney top and cap to allow warm humid air to go out and protecting the product from rain and other foreign materials. The height of the chimney and the hot air inside it creates a pressure difference between its top and bottom thereby creating forced movement of air through the rice bed to the top of the chimney. Although this dryer is designed to dry rice only but other food products or grains which require slow and low temperature drying may also be dried. The drying rate will depend on the depth of the bed, initial moisture content of the material, solar insolation, ambient temperature, and the design of the dryer. It is experienced that if the material in the dryer remained untouched then the material in the lower layer gets overheated and overdried while at the top remained underdried. Therefore, stirring of material and drying in thin layers is recommended.

Hybrid Solar Dryer

A hybrid solar dryer is a solar dryer that uses additional energy sources to help dry products. These dryers can use electricity, biomass, thermal energy storage, or wind energy. Hybrid solar dryer work as, Solar energy During sunny days, the dryer uses direct solar energy to dry products. Backup energy: When there's not enough sunlight, the dryer uses stored heat or backup energy to dry products. Heat exchanger: The dryer uses a heat exchanger to store heat energy collected during the day.

Benefits of hybrid solar dryer

Continuous operation: Hybrid solar dryers can operate continuously.
Better drying quality: Hybrid solar dryers can produce higher quality dried products.
Less affected by weather: Hybrid solar dryers are less affected by weather conditions. Uses of hybrid solar dryers can be used to dry agricultural products like grains, legumes, onions, and fruits

Cabinet type solar dryers

A cabinet type solar dryer is a box-like device that uses solar energy to remove moisture from food and other materials. It has two main parts:a dryer and a collector. The drying chamber, trays, exhaust pipe, and exhaust fan are all part of the dryer. The trays are placed on stainless steel or poly-coated iron net. The collector's main part is the absorber plate, which is usually made of corrugated iron painted black to absorb more solar energy. The solar panel is placed above the dryer, but not directly on top of it. The outer cover is made of an insulating material like PVC sheet. The solar panel heats air, which then passes through the drying chamber. The heat from the air evaporates moisture from the food being

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dried. The dehydrated food is shelf stable and lightweight. Uses of Cabinet type solar dryers are used to dry fruits, vegetables, and crops. They are also used to reduce the moisture content of sensitive products.

Tunnel type solar dryer

Solar Tunnel Dryer is a tunnel type chamber, which is used for drying of various crops using Green House effect. It helps to preserve the food and also increase the shelf life of the product. It is covered with multi wall Polycarbonate sheet that traps solar energy and has an insulation effect, thereby maintaining high temperature for a longer period of time. Further solar dryer filters out the UV radiations, which helps products to retain the colour. The dryer can protect from rain, insect, dust, and rodent. These dryers are modular, easily transportable/ portable, and constructed according to users requirement. Benefits of tunnel type solar dryer is preserves food and increases its shelf life, Protects products from rain, dust, insects, and rodents, Can be used to dry large quantities of products, Can be used for small drying capacities, Can be constructed to meet the user's needs. Dried products retain their natural color and have a uniform look as well as texture that can help better market prices. Drying in the sun can turn agricultural products black but not when a solar tunnel is used.

Tomatoes, onions, figs, sapota, mango, amla, chillies and grapes can easily be dried within the solar tunnel.

Working of solar dryers

Solar drying is environment-friendly and is done using solar dryers. Solar dryers help provide more heat than the atmospheric temperature. In a solar dryer, air enters the drying chamber through the process of natural convection or through an external source like fan,pump,suction device,etc. Air gets heated as it passes through the chamber and then partially cools as it absorbs moisture from the food product placed in the chamber. Then, the humid air is removed by an exhaust fan or chimney. To provide a consistent air flow in the drying chamber,pipes are used to link the drying chamber and solar collector. The use of pipes lets air to move individually to each of the trays,ensuring that air is spread uniformly across each tray. a zigzag shaped solar absorber plate. The surface area of this unusual shaped solar absorber increases, allowing for a greater quantity of heat to be absorbed and a higher heat transfer efficiency. Solar drying refers to a technique that utilizes incident solar radiation to convert it into thermal energy required for drying purposes. Most solar dryers use solar air heaters and the heated air is then passed through the drying chamber (containing material) to be dried. The air transfers its energy to the material causing evaporation of moisture of the material.

Application of solar dryer

Solar dryer have many applications in drying agricultural products, industrial waste, herbs, sewage. Solar dryers can be used to dry herbs and spices like tulsi, neem, cashew, paddy, mushroom, tea leaves, and coffee beans. Solar dryers can be used to dry fruits and vegetables like mangoes, bananas, grapes, potatoes, and more. Solar dryers can be used to dry industrial waste. Solar dryers can be used to dry lignite coal for power generation. Solar dryers are used to improve the quality of the dried product and reduce the drying time compared to sun drying. Different types of crops are dried with the help of solar dryers such as paddy, oilseed, carrot, herb and spices, and vegetables. Commercial utilization includes industrial applications of solar drying such as drying of porous materials, bricks, leather, wood and timber, textile, cement, polymers, paper and allied products, tea, dairy products, waste-water treatment, sewage sludge, and pharmaceutical processes. The rate of drying increases with higher temperature and movement of air in the chamber. Food is enclosed in the dryer and therefore protected from dust, insects, birds, and animals. Higher temperature prevents insect infestation and the faster drying rate reduces the risk of spoilage by microorganisms. A dryer can be constructed from locally available materials at a relatively low cost. Solar dryers last longer. A typical dryer can last 15-20 years and will need minimum maintenance.

III. CONCLUSION

Solar drying technology has become popular in developing countries and overcomes the problems. The review shows that different types of dryers have their advantage and their limitations. Hybrid dryers are stand-alone and can operate during the off sunshine period also. Solar dryers are emerging as an alternative for conventional methods of heat

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generation and are also beneficial in the industrial and agricultural sectors such as food, dairy, cement, waste water treatment, textile, wood, and timber for achieving better drying performance. The design, development and performance evaluation of various types of solar dryers were reviewed. The status Solar dryers are emerging as an alternative for conventional methods of heat generation and are also beneficial in the industrial and agricultural sectors such as food, dairy, cement, waste water treatment, textile, wood, and timber for achieving better drying performance of solar dryers with respect to the developing countries was reviewed. The solar drying technologies which facilitate the drying of crops in the off sunshine hours. The application of solar dryers in industries and agricultural were reviewed.

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