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Solar Drying Technologies: A review

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Abstract:- Solar drying is one of the application of solar energy. Drying means moisture removal from the product. Drying is helpful in preserving food product for long time; it prevent product from contamination. Direct solar drying, indirect solar drying, and mixed mode solar drying these are different solar drying methods. Primarily open to the sun or direct sun drying technique is used. However, it has some disadvantages. These disadvantages can be eliminated by indirect type of dryer which is used for drying products as application of solar energy. In this paper, we studied the different technique of drying and various modes of solar drying.

Keywords:- Direct type solar dryer, Indirect type solar dryer, Natural circulation solar dryer, Forced circulation solar dryer.

I. INTRODUCTION

Drying means preservation of food, fruits and vegetables for long time with good quality. It is a process of moisture removal due to simultaneous heat and mass transfer. Agricultural products, especially fruits and vegetables require hot air in the temperature range of 45–60˚C for safe drying. When any agricultural product is drying under controlled condition at specific humidity as well as temperature it gives rapid superior quality of dry product [1]. Drying involves the application of heat to vaporize moisture and some means of removing water vapor after its separation from the food products. It is thus a combined and simultaneous heat and mass transfer operation for which energy must be supplied. The removal of moisture prevents the growth and reproduction of microorganisms like bacteria, yeasts and molds causing decay and minimizes many of the moisture-mediated deteriorative reactions. It observed that reduction in weight and volume, minimizing packing, storage, and transportation costs and enables storability of the product under ambient temperatures. These features are especially important for developing countries [2].

Drying process takes place in two stages first one happens at the surface of the drying material at constant drying rate and is similar to the vaporization of water into the ambient and second stage is according to properties of drying product with decreasing drying rate [3]. Previously open sun drying is used for drying product. In this method, the crop is placed on the ground or concrete floors, which can reach higher temperatures in open sun, and left there for a number of days to dry. Capacity wise, and despite the very rudimentary nature of the process, natural drying remains the most common method of solar drying. This is because the energy requirements, which come from solar radiation and the air enthalpy, are readily available in the ambient environment and no capital investment in equipment is required. The process, however, has some serious limitations. The most obvious ones are that the crops suffer the undesirable effects of dust, dirt, atmospheric pollution, and insect and rodent attacks. Because of these limitations, the quality of the resulting product can be degraded, sometimes beyond edibility. All these disadvantages can be eliminated by using a solar dryer [4].

The purpose of a dryer is to supply more heat to the product than that available naturally under ambient conditions, thus increasing sufficiently the vapour pressure of the crop moisture. Therefore, moisture migration from the crop is improved. The dryer also significantly decreases the relative humidity of the drying air, and by doing so, its moisture-carrying capability increases, thus ensuring sufficiently low equilibrium moisture content. A classification chart of drying equipment on the basis of heat transfer is shown in Fig [1.1]. This chart classifies dryers as direct or indirect, with subclasses of continuous operation. Solar energy drying systems are classified primarily according to their heating modes and the manner in which the solar heat is utilized. They are classified into two main methods:

1. Active dryers.
2. Passive dryers.

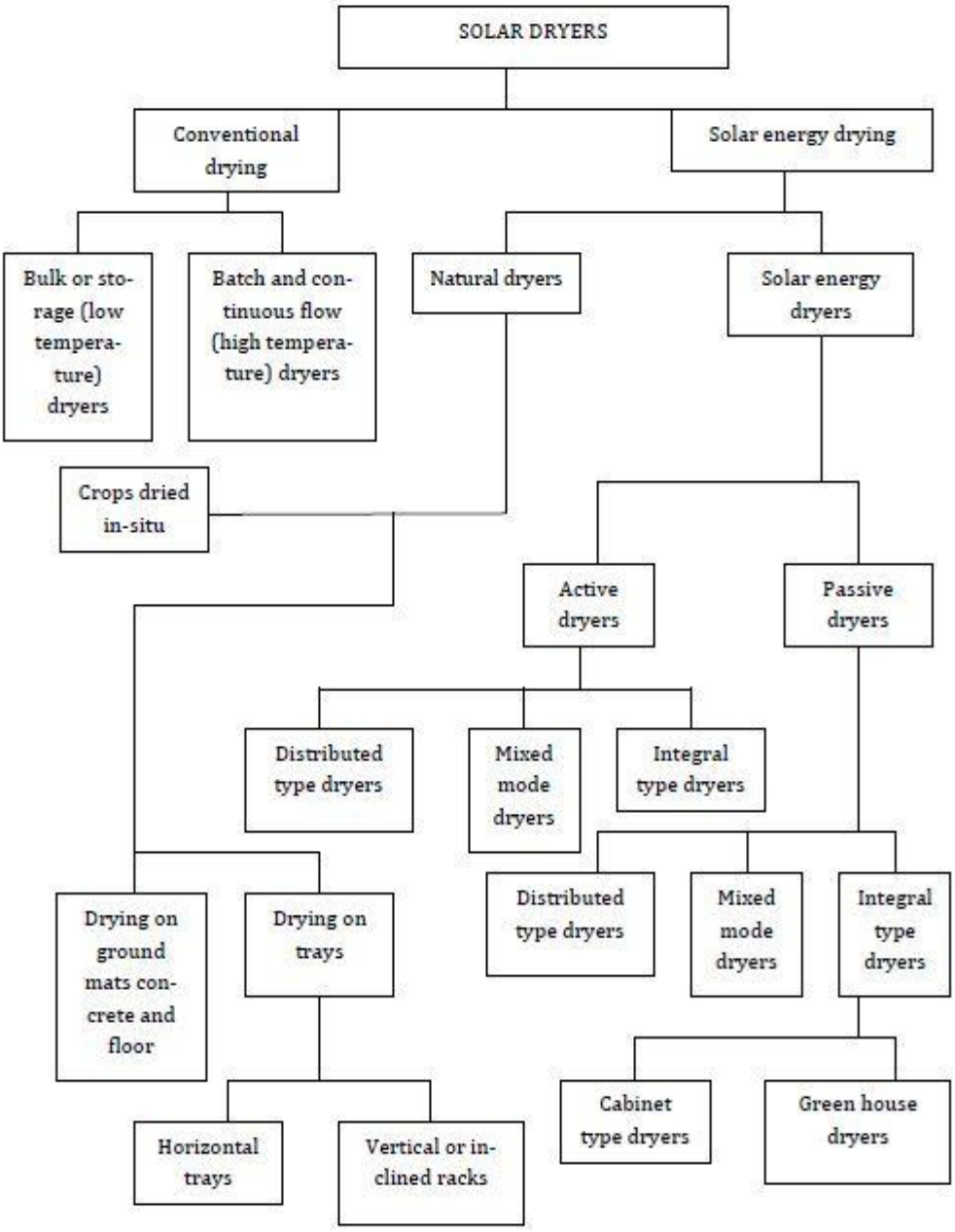

Fig 1.1: Classification of dryer and drying mode [5].

Active dryer means hybrid solar dryer and passive dryer conventionally termed as natural circulation dryer. According to the mechanism solar dryer can be divide into four categories:

1. Sun or natural dryer- The crop is placed on the ground open to the sun, which can reach higher temperatures in open sun, and left there for a number of days to dry. This type of method is useful for drying grains. Capacity wise, and despite the very rudimentary nature of the process, natural drying remains the most common method of solar drying. Following are some disadvantages of sun or natural dryer [5, 6].

Disadvantages:

a. Time required for drying is more as compaired to other methods.
b. Output product quality is poor.
c. Product obtained is contaminated by dirt, dust as well as by bacteria.
d. Drying rate is poor in sun or natural drying.

2. Direct solar dryer- This is simple type of dryer in which material to be dried is placed in an enclosure with transparent covers. Heat is generated by absorbing solar radiation on the product itself and internal surface of drying chamber. Material is led on drying chamber for 20-30 days. Following are some advantages and disadvantages of direct solar dryer [5, 7]:

Advantages:
a. Contamination of product due to enclosure with transparent cover is less.
b. Product quality obtained is higher than open to the sun drying.
Disadvantages:
a. Time required for product drying is same as sun or natural drying.
3. Indirect solar dryer- Indirect solar drying is the new technique of product drying. It is very efficient method than the direct type of solar drying. In this method the atmospheric air is heated in flat plate collector or concentrated type solar collector. The heating process is either passive or active. This hot air then flow in the cabin where products are stored. Therefore moisture from the product may lost by convection and diffusion. Drying rate is high as compared to the direct solar dryer. Following are some advantages and disadvantages of indirect solar dryer [5, 7]:
Advantages:
a. This technique avoids contamination of final product.
b. It is very efficient method than the direct type of solar drying.
c. Maintain the quality of product by avoiding direct exposure in solar radiations.
d. Time required for drying some product is less.
e. Final conditions of product are avoided on the circumstances of natural phenomenon.
Disadvantages:
a. Requires more initial cost.
b. Need maintenance after particular period of time.
4. Mixed mode solar dryer- As the name indicates it is combined action of the solar radiation incident directly on the material to be dried and the air pre-heated in the solar air heater furnishes the energy required for the drying process. For designing of this type of dryer various factors are to be consider are: 1] Thermal performance. 2] Cost. 3] Lifetime, durability, maintenance and ease of installation. Following are some advantages and disadvantages of mixed mode solar dryer [8]:

Advantages:
a. Rapid rate of drying with safe moisture level in product.
b. Time required for drying is less than other drying techniques.

Disadvantages:
a. Quality of dry grain obtained over a year is less than indirect type of dryer.
b. Cost required for maintenance.
c. Capital cost required is higher.

II. MECHANISM OF DRYING AGRICULTURAL PRODUCTS AND CLOTHS

Drying is most cost effective application of solar energy. There are various products which are dried by solar dryer like various fruits, grains, meat, timber, fish, cloths. Food products are preserved by drying. In developing nations, open to the sun drying technique is used for drying agricultural products. Open to the sun drying means products are exposed directly to sun, allowed to absorbed solar radiation. It was reported that this method has many disadvantages like poor quality, contamination of product [9]

The dryer is container which is powered by electricity or fuel as source of heat, design for house product like cloths or agricultural product and used air for drying the products is called as mechanized form of dryer. This is faster dryer but it need large initial cost for various equipment's as well as for fuel. Following gives advantages and disadvantages between Solar dryer with other means of drying [10].

2.1 Comparison between Solar dryer with Mechanized form of dryer:

Advantages:
a. It reduces environmental impact.
b. Easily managed.
c. Prevent fuel dependence.
d. Often less expensive.
Disadvantages:
a. Requires adequate solar radiation.
b. Hot and dry climate preferred (relative humidity below 60% needed).
c. Requires more time.

2.2 Comparison between Solar dryer with open air drying.

Advantages:

a. It gives better quality of drying product.
b. It reduces losses and bacterial contamination.
c. Requires less area for drying.
d. May reduce labor required.
e. Drying time reduces.

Disadvantages:

a. More expensive.
b. It may requires some parts material to be import.

III. PRECEDING RESEARCH DONE ON SOLAR DRYER

Drying is an essential process for preservation of agricultural products. Drying is a process of moisture removal from the products. For rapid and safe drying there is need of controlled conditions of temperature and humidity which gives superior quality of the product.

3.1. Direct type solar dryer: The figure 4.1 shows simplest type of cabinet dryer. Here moisture is removed from top; air enters into cabinet from below and leaves from top. This is open to the sun drying type of dryer only difference is food product is covered with the glass cover. When sun light fall on the surface of glass then three things happens, first is some light is absorbed, some light is reflected back from the glass, some light is transmitted. As part of radiation absorbs by surface of crop which causes increase in temperature. The glass cover reduces direct convective losses to the ambient and which plays important role in increasing temperature of agricultural product and cabinet temperature. It is small box made up of wood, having 1m length and 0.3m width. The temperature recorded in this cabinet dryer is 80˚C. There are some disadvantages of cabinet dryer like, i] drying time required is large due to natural convection of air flow hence low heat and moisture transfer coefficient. ii] hence efficiency is low.

3.2 Indirect type of solar dryer: This type of dryer differs from direct dryer by heat transfer and vapor removal. In this method atmospheric air heated in flat plate collector as shown in figure 4.3. then this hot air from flat plate collector is flow in the cabin where products are placed. The moisture from this type of dryer is removed by convection as well as by diffusion. This figure 4.3 shows forced circulation solar dryer. Similarly instead of flat plate collector concentrating collector is also used for drying application. Temperature obtained from this type of collector is large as compared to flat plate collector. For fast drying as well as for cloth drying this type of collector can be used. A small dish type solar air heater connected to a drying chamber for drying apricots. Results show that efficiency improved from 20% at natural flow rate of 0.01kg/sec to 42.6% at a high convective flow rate of 0.21 kg/sec. apricots took 13 hours for removing moisture from 85% to 8% [12].

3.3 Mix mode solar dryer: Mix mode solar dryer is the combination of direct and indirect type of solar dryer. Product is dry by directly exposure to the sun light and also by hot air supplier on it. Air is heated in a collector and then this hot air is supplied to the drying chamber and drying chamber top is made up of glass cover. Which can directly absorbs solar radiation. In this way drying rate is higher as compared to direct solar drying. Figure 4.4 shows schematic views of mixed mode natural convection solar crop dryer (MNCSCD). The governing equations were derived with respect of the drying air temperature, humidity ratio, product temperature and its moisture content [13].Olalusi and Bolaji constructed a mixed- mode solar dryer for food preservation. It was found that inside temperature of drying chamber was up to 74% after 12 pm for about 3 hours. drying rate obtained is 0.62kg/h and system efficiency obtained is 57.5% [15]. Tripathy and kumar gives information of dryer in which flat plate collector placed in series. They used this dryer for drying potato slices of diameter 0.05m and thickness 0.01m [14].

Various research work related to drying process for agricultural products like mango slices [16, 17], Banana [18, 19], strawberry [16], grapes [21, 22, 23].

IV. FIGURES

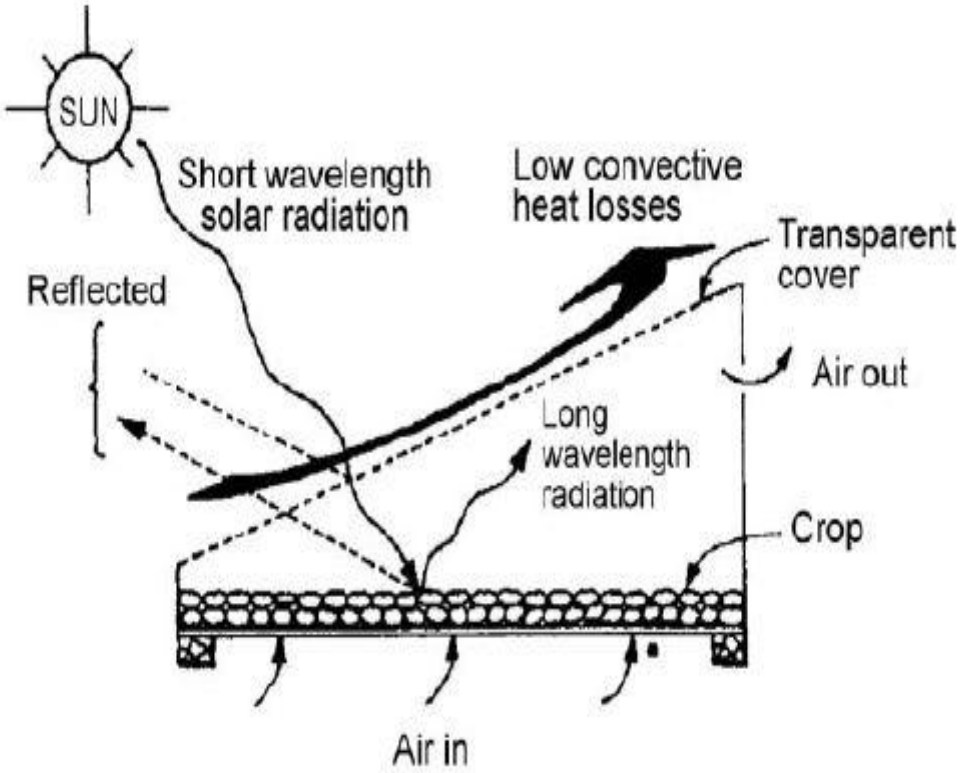

Fig 4.1: Working of Cabinet type of dryer [5].

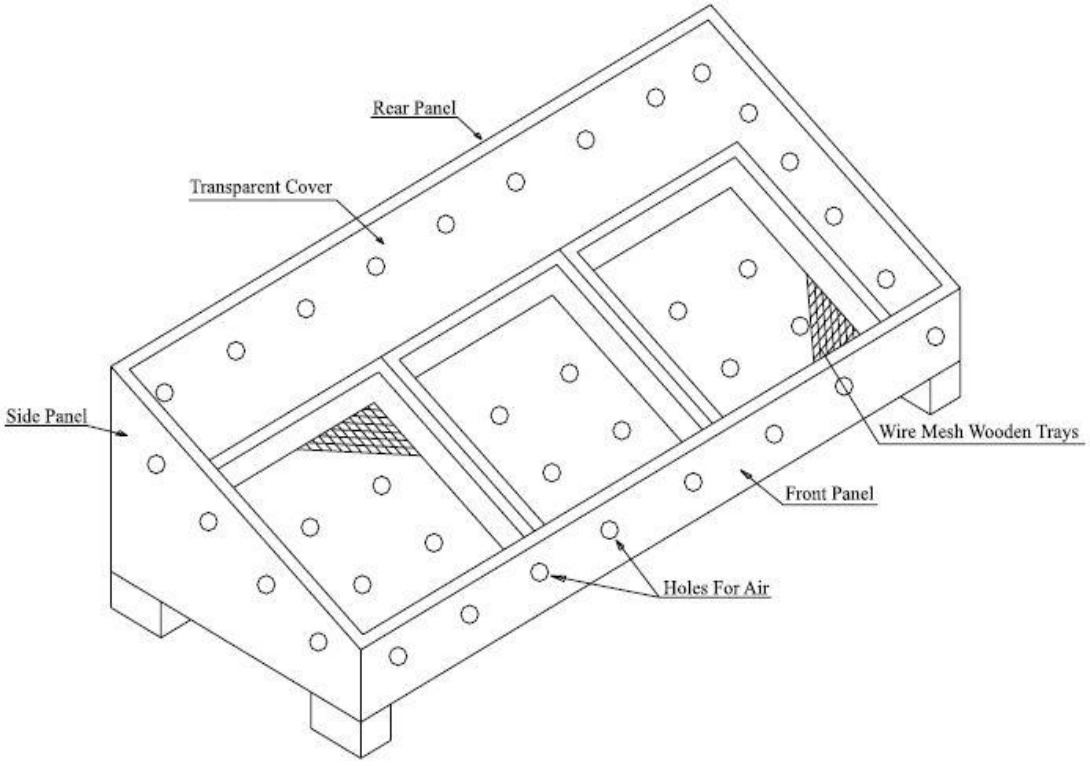

Fig 4.2: Actual solar cabinet dryer [11].

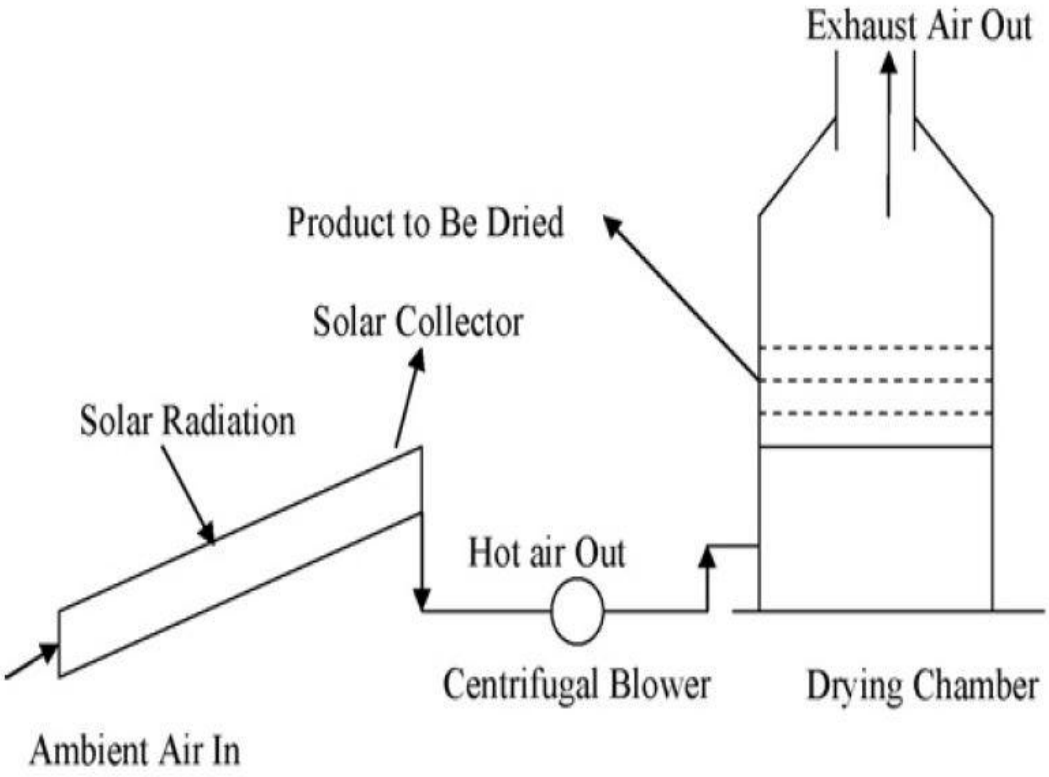

Fig 4.3: Indirect type of solar dryer [5].

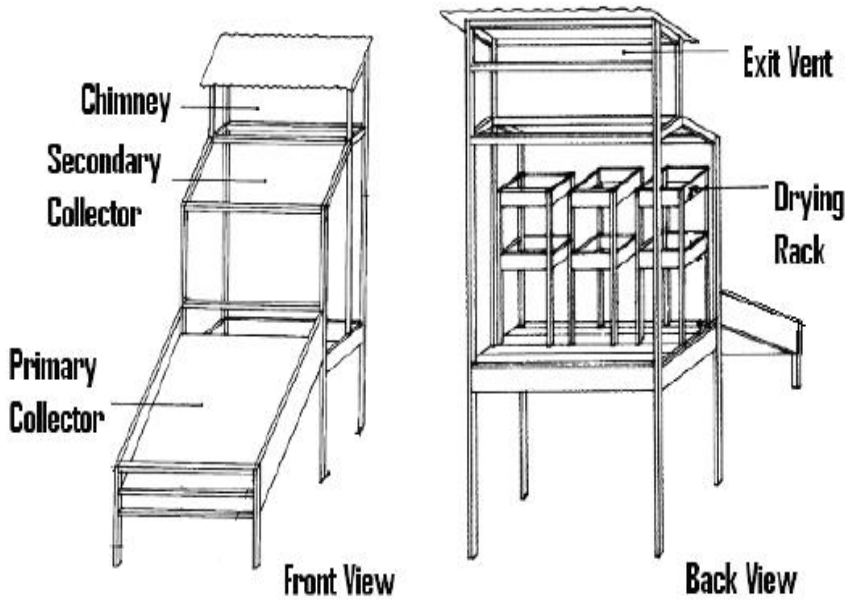

Fig 4.4: Schematic views of the Mixed Mode Natural Convection Solar Crop-Dryer (MNCSCD) [13].

V. CONCLUSION

Solar dryer is the best alternative option to avoid disadvantages of conventional drying methods. Solar dryer is designed particularly for drying agricultural products. In this paper direct, indirect natural, indirect forced convection drying. It is found that time required for drying in mixed mode solar dryer is less than other type of dryer. Force circulation drying gives better result than natural circulation solar dryer.

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