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Review Paper on Solar Dryers

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Abstract— ***This work is an attempt to utilize the benefits of using forced convection solar dryers through the use of a ventilator in the remote areas where electricity and other power sources are non-existent. The solar air dryer was designed with solar collector of tilt angle 11.0138' so that the temperature remains much higher than the ambient temperature. The tilt angle is chosen based upon the latitude of Coimbatore 11*** ***' N. The main objective is to show that the temperatures inside the dryer and the air-heater is higher than the ambient temperature during most hours of the day-light. The drying of food items in the solar air dryer will be higher when compared with open air-drying of similar items. This will show that the drying with the solar air dryer will provide better results than open air-drying. The results will also depend upon the dryer performance on the proper air circulation through the system***

Keywords— ***solar collector, direct type solar dryer, indirect type solar dryer, air blower, forced convection***

I. Introduction

Drying is a important process applicable for both industrial and agriculture products. Drying reduces the bacterial growth in the products. Open air solar drying method is used frequently to dry the agricultural products. But this method has some disadvantages .Solar is one of the renewable and sustainable sources of power that attracted a large community of researchers from all over the world.

Open air and uncontrolled sun drying is still the most common method used to preserve and process Agricultural product. But uncontrolled drying suffers from serious problem of wind born dust, infestation by insect, product may be seriously degraded to the extent that sometimes become market valueless and resultant loss of and have to the food quality may have adverse economic effects on domestic and international market.

Solar dryers are devices that use solar-energy to dry substances, especially food .This is largely due to its abundant in both direct and indirect form. As such the development of efficient and inexpensive equipment for the drying of agricultural using solar power evolved thereby improving the quality of the products as well as improving the quality of life. The use of solar dryers in the drying of agricultural products can significantly reduce or eliminate product wastage, food poisoning and at the sometime enhance productivity of the farmers towards better revenue derived.

II. TYPES OF SOLAR AIR DRYER

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:

- Active solar-energy drying systems (most types of which are often termed hybrid solar dryers)
- Passive solar-energy drying systems (conventionally termed natural-circulation solar drying systems).

Three distinct sub-classes of either the active or passive solar drying systems can be identified which vary mainly in the design arrangement of system components and the mode of utilization of the solar heat, namely:

- Direct (integral) type solar dryers;
- Indirect (distributed) type solar dryers.

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. In indirect solar dryers, solar radiation is not directly incident on the material to be dried. Air is heated in a solar collector and then ducted to the drying chamber to dry the product. Specialized dryers are normally designed with a specific product in mind and may include hybrid systems where other forms of energy are also used .Although indirect dryers are less compact when compared to direct solar dryers, they are generally more efficient. Hybrid solar systems allow for faster rate of drying by using other sources of heat energy to supplement solar heat. 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.

2.1 OPEN SUN DRYING (OSD):

The short wave length solar energy falls on the uneven product surface. A part of this energy is reflected back and the remaining part is absorbed by the surface. The absorbed radiation is converted into thermal energy and the temperature of product stars increasing. This results in long wavelength radiation loss from the surface of product to ambient air through moist air. In addition to long wave length radiation loss there is convective heat loss too due to the blowing wind through moist air over the material surface. Evaporation of moisture takes place in the form of evaporative losses and so the material is dried. Further apart of absorbed thermal energy is conducted into the interior of the product. This causes a rise in temperature and formation of water vapour inside the material and then diffuses towards the surface of the and finally losses thermal energy in the end then diffuses towards the surface of the and finally losses the thermal energy in the form of evaporation. In the initial stages, the moisture removal is rapid since the excess moisture on the surface of the product presents a wet surface to the drying air. Subsequently, drying depends upon the rate at which the moisture within the product moves to the surface by a diffusion process depending upon the type of the product.

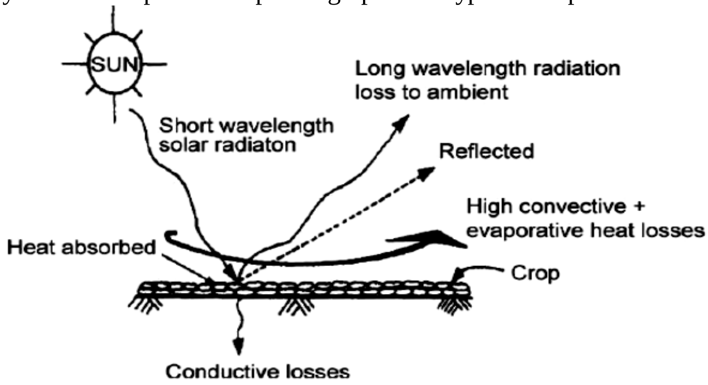

Figure.1 Working principle of open sun drying

In open sun drying, there is a considerable loss due to various reasons such as rodents, birds, insects and micro-organisms. The unexpected rain or storm further worsens the situation. Further, over drying, insufficient drying, contamination by foreign material like dust dirt, insects, and micro-organism as well discolouring by UV radiation are characteristic for open sun drying. In general, open sun drying does not fulfill the international quality standards and therefore it cannot be sold in the international market. With the awareness of inadequacies involved in open sun drying, a more scientific method of solar-energy utilization for drying has emerged termed as controlled drying or solar drying. The main features of typical designs of the direct and of indirect types solar –energy dryers.

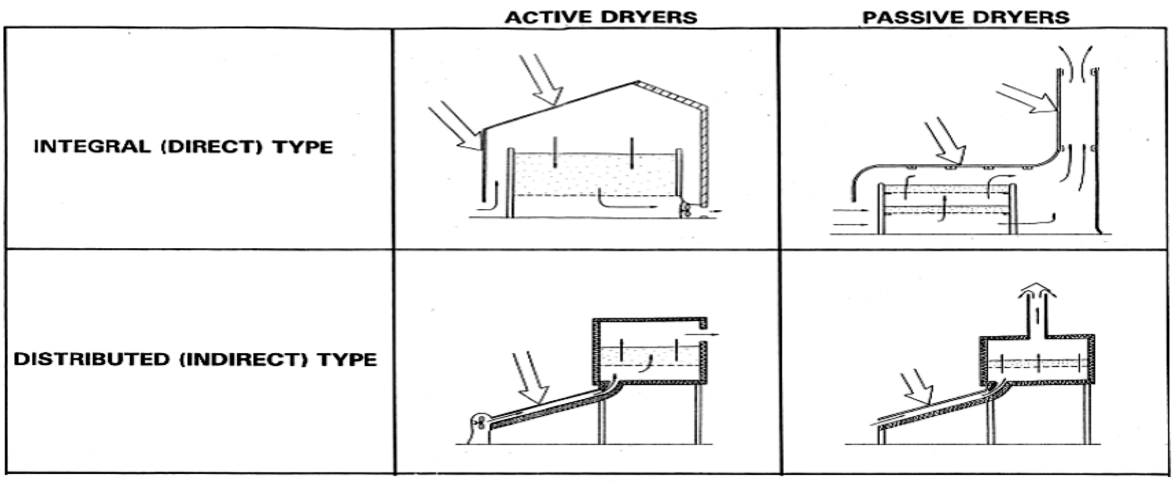

Figure 2.dryers types

2.2 DIRECT TYPE SOLAR DRYING (DSD)

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. Further, a part of transmitted radiation is reflected back from the surface of the product. The remaining part is absorbed by the surface of the material. Due to the absorption of solar radiation, product temperature increase and the material starts emitting long wave length radiation which is not allowed to escape to atmosphere due to presence of glass cover unlike open sun drying. Thus the temperature above the product inside chamber becomes higher. The glass cover server one more purpose of reducing direct convective losses to the ambient which further become beneficial for rise in product and chamber temperature respectively [. However, convective and evaporative losses occur inside the chamber from the heated material. The moisture is taken away by the air entering into the chamber from below and escaping through another opening provide at the top . 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. The product samples are placed on a perforated tray that allows the air to flow through it and the material. Solar radiation passes through the transparent cover and is converted to low-grade heat when it strikes an opaque wall. This low-grade heat is then trapped inside the box by what is known as the greenhouse effect. Simply stated, the short wavelength solar radiation can penetrate the transparent cover. Once converted to low-grade heat, the energy radiates. Reference reported a modification of the typical design. This cabinet dryer was equipped with a wooden plenum to guide the air inlet and a long plywood chimney to enhance natural-circulation. This dryer was reported to have accelerated the drying rate about five times over open sun drying.

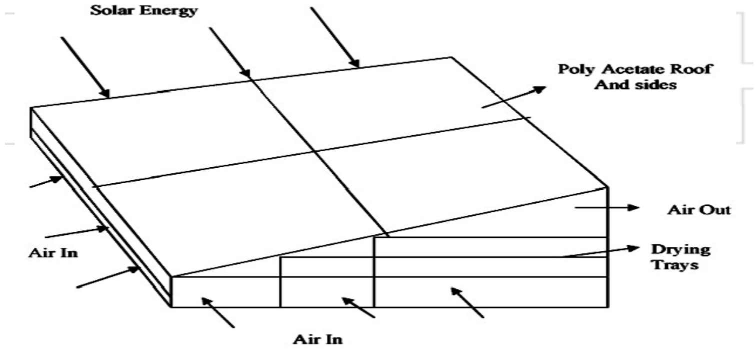

Figure.3 Direct solar drying (Natural convection type cabinet drier)

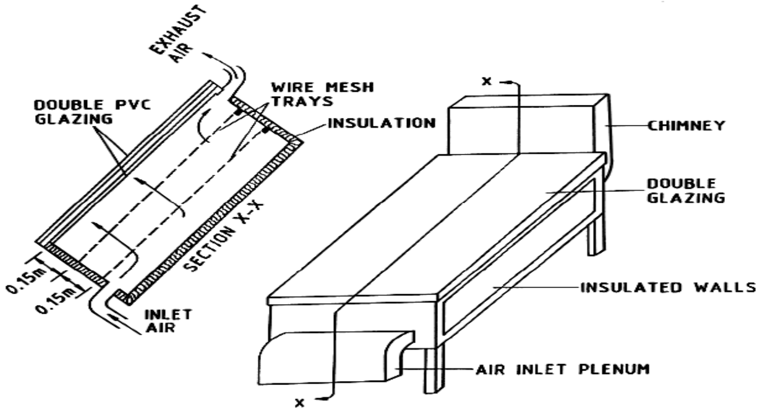

Fig.4 A modified natural-circulation solar-energy cabinet dryer

2.3 INDIRECT TYPE SOLAR DRYING[ISD]

This type is not directly exposed to solar radiation to minimize discolorations and cracking. Reference has proposed and analysed reverse absorber cabinet dryer (RACD), the schematic view of RACD . 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. The absorber can be selectively coated. The inclination of the glass cover is taken as 45o from horizontal to receive maxi 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 .

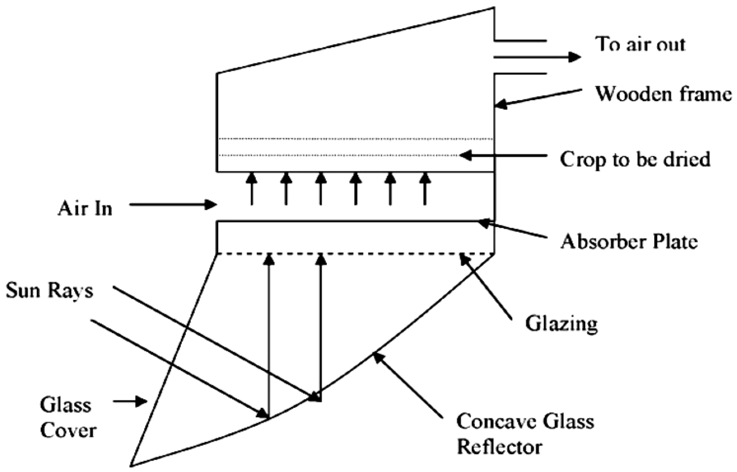

Figure.5 Reverse absorber cabinet drier

This describes another principle of indirect solar drying which is generally known as conventional dryer. In this case, a separate unit termed as solar air heater is used for solar energy collection for heating of entering air into this unit. The air heater is connected to a separate drying chamber where the product is kept. The heated air is allowed to flow through wet material. Here, the heat from moisture evaporation is provided by convective heat transfer between the hot air and the wet material. The drying is basically by the difference in moisture concentration between the drying air and the air in the vicinity of product surface. A better control over drying is achieved in indirect type of solar drying systems and the product obtained is good quality.

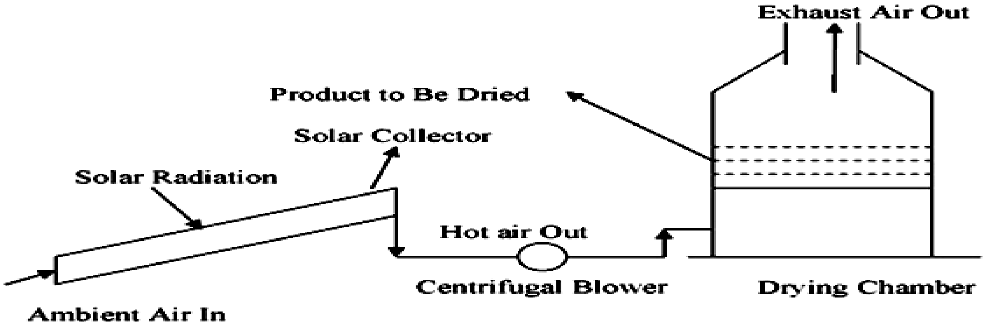

Figure.6 Indirect solar dryer (Forced convection solar dryer)

There are several types of driers developed to serve the various purposes of drying products as per local need and available technology. The best potential and popular ones are natural convection cabinet type, forced convection indirect type and green house type. Apart from the above three, as seen from the literature, Solar tunnel drier is also found to be popular.

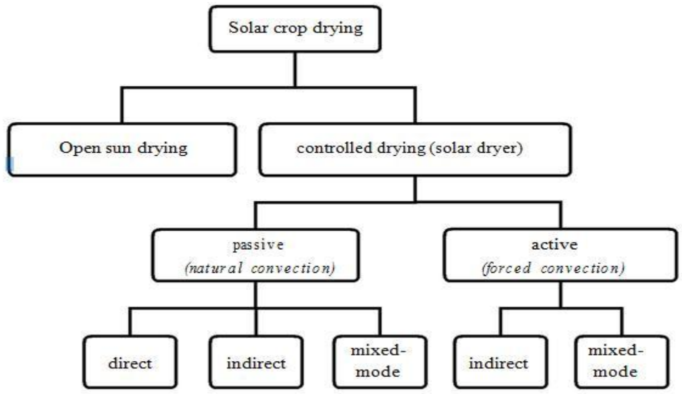

Figure.7 Classification of crop drying using solar energy

2.4 ACTIVE SOLAR CABINET DRYER:

Active solar dryers are also termed as forced convection or hybrid solar dryers. Optimum air flow can be provided in the dryer across the drying process to control temperature and moisture in wide ranges independent of the weather conditions. Moreover, the bulk depth is less restricted and the air flow rate can be controlled. Hence, the capacity and the reliability of the dryers are enhanced considerably compared to natural convection dryers. It is generally agreed that well designed forced-convection distributed solar dryers are more effective and more controllable than the natural circulation types. The use of forced convection can reduce drying time by three times and decrease the required collector area by50%. Consequently, dryer using fans may achieve the same through put as a natural convection dryer with a collector six times as large. Fans may be powered with utility electricity if it is available, or with a solar photovoltaic panel. Almost all types of natural convection dryers can be operated by forced convection as well.

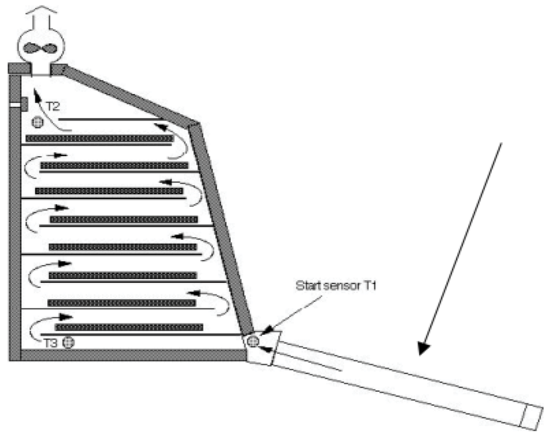

Figure.8 Active solar cabinet dryer

2.5 CABINET DRYERS WITH BACK-UP HEATING:

Generally, solar dryer utilizes solar energy to heat the air which limits their efficiency only for sunny days. One major disadvantage of solar dryers is that they are normally not used with any form of back-up heating . For commercial producers, this factor limits their ability to process a crop when the weather is poor or during night. It also extends the drying time because drying can only occur during the daytime when there is adequate solar radiation. This not only confines the production but also results in an inferior product. For commercial producers, the ability to process continuously with reliability is important to meet up the market demand.

Biomass, particularly wood, is the most common source of energy in rural areas of developing countries, provided that over use of it should not create the unsustainable pressure on the local resources .Wood can be a natural source of energy, if usage is balanced by new plantation. Currently, it is often burned inefficiently and so there is need for simple, affordable combustion devices, which can be used to complement appropriate solar technologies such as the cabinet Dryer

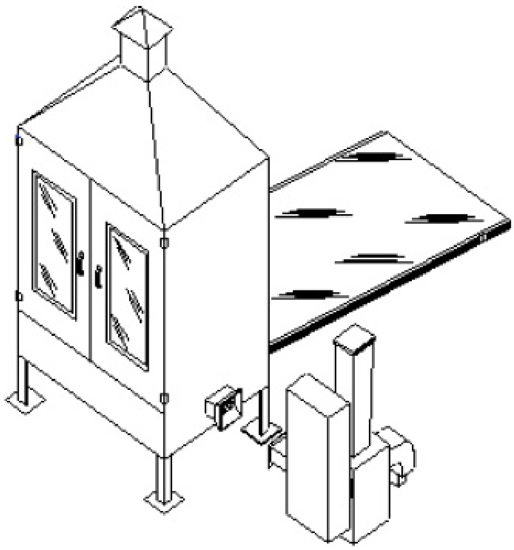

Figure.9 Cabinet dryers with back-up heating

2.6 SOLAR DRYING SYSTEM USING PHASE CHANGE MATERIAL

A phase-change material (PCM) is a substance with the properties like a high heat of fusion (Latent Heat), melting and solidifying at a certain temperature and capable of storing and releasing large amounts of heat energy during phase change. It is also known as "Latent Heat Storage (LHS) units".

Broadly, Heat energy are of two types:

a. Sensible Heat (changes Temperature).

b. Latent Heat (No change in Temperature).

PCMs changes its phase at a constant temperature, by storing a large amount of latent heat and again changes back its phase by releasing the stored heat, which is used for heating or drying purpose. Solid-Liquid PCMs are used generally used as handling of material in this stage is easier. The thermal energy transfer occurs when a material changes from solid to liquid, or liquid to solid. Initially, these solid–liquid PCMs perform like conventional storage materials; their temperature rises as they absorb heat [26]. PCMs absorb and release heat at a nearly constant temperature. They store 5-14 times more heat per unit volume than sensible storage materials such as water .Pluss® Polymers Pvt Ltd is a materials research and manufacturing company involved in the field of Speciality Polymeric Additives and Phase Change Materials (PCMs) for thermal energy storage. A schematic diagram of PCM
assisted solar dryer is given below

2.7 INDIRECT ACTIVE HYBRID SOLAR-ELECTRICAL DRYER SYSTEM:

In hybrid type of solar dryer, an additional source of heating air is provided along with solar collector so that the overall temperature of the drying air can be increased. This system is also applicable where continuous drying is required and solar radiation is not available. The indirect active hybrid solar–electrical dryer was fabricated and installed at LENREZA laboratory (Laboratory of New and Renewable Energy in Arid Zones), university of Ouargla, Algeria. It consisted mainly of a flat plate solar collector, drying chamber, electrical fan, resistance heater (3.75 kW: accuracy ± 2%) and a temperature controller. The solar air collector has an area of 2.45 m2, and was inclined at an angle of 31° (latitude of Ouargla city) with the horizontal facing south all the time and used a black painted metal of 0.002 m thickness to absorb most of the falling solar radiation. The cover losses were minimized by placing a glass cover of 0.005 m thickness over the top of the black absorbing metal sheet, and a layer of polystyrene was sandwiched between two parallel metal sheets and back insulator to provide insulation. The air was passed under the glass sheet, between the glass and the absorber. The solar collector was connected directly to the drying chamber without any air ducts to reduce pressure drop. The drying cabinet constructed with a galvanized iron box with insulated polystyrene walls of dimensions 1.65 m , 0.60 m , 1.00m containing six product trays each tray has an area of 0.4 m2 with possibilities to extend up to eight product trays. The drying trays were made of a wooden frame on all four sides and a wire mesh on the bottom to contain the samples and/or to change the position of the trays. The door of the dryer was properly sealed to forbid air leakage. In solar drying process, the auxiliary heater was used to adjust the drying air temperature. The preliminary heating of air was done by solar radiation which was again heated by electrical resistance, if its temperature was less than drying temperature required; which is controlled thermostatically and then ventilated by an exhaust fan through the product to the environment. The exhaust fan of 20 cm diameter was manually controlled by a valve, allowing the choice of the desired air mass flow. The fan was fixed below product trays at the bottom of the dryer to check an even distribution of air and to remove the humidity of the product to the surrounding.

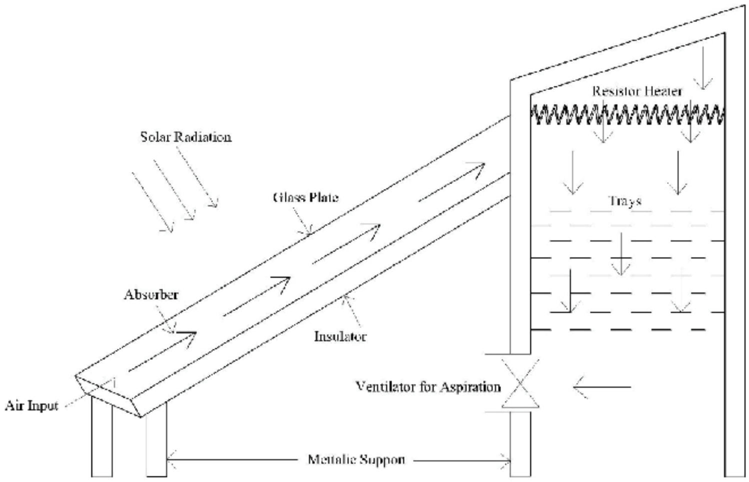

Figure.10 Solar drying system with indirect heating

III. CONCLUSION

Thus solar crop dryer proves to be an best option to dry the crops. It has some pros and cons as well. But solar crop dryer proves to be an best alternative option then the conventional methods. The crops obtained from this kind of method is highly nutritious, dust-free, safer and can be dried in limited time. Thus this paper reviews the various types of drying methods and dryers available.

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