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A Review of Solar Energy use in Drying

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ABSTRACT

Energy consumption in drying food products is increasing day by day. Therefore, forreduction of energy consumption, it is required to bring the solar energy technology in picture. In comparison to other energy sources, solar energy is the best alternative because it is a clean source of energy. For preservation of the agricultural products, mostly open sun drying technology is used in developing countries. In this technique, the products get affected by insects, dust, rain, soil and many more issues. To overcome these problems, different types of solar dryers are designed and evaluated which shows that solar dryer are faster, effective, hygienic and better to promote quality products when compared to open drying technique. The solar drying is not possible during night time which subsequently interrupts the dehydration process. To overcome this, some integrated or hybrid drying systems are designed.The drying of different products require different temperature ranges and to maintain the product quality as well as color, it is important to dry products at suitable temperature ranges which can be achieved in solar dryer. In this communication, a comprehensive review on different type of solar drying systems for different applications has been carried out which helps to choice the best technology based on the requirements.

KEYWORDS*:*Solar dryer, drying technologies, advancements, designs.

INTRODUCTION

All the developing and developed countries have been facing food problem, due to population explosion which eventually has created an imbalance in food distribution. These days, poor storage techniques degrade the quality and quantity of food products. However, it is also impossible for farmers to increase production of food with decreasing availability of land to solve this problem. Therefore storage of food grain through drying is a major channel in terms of safety and security of food items. Energy consumption in drying is uncertain and with the rise in price and depletion of commercial energy sources, have forced individuals to shift toward the renewable energy sources, which is abundant. Few years back, open sun drying is mostly used to dry food grains, fruits, leafy vegetable and spices. The major advantage of such drying technique is their storage for long terms but degradation in the quality of food besides time consuming is an issue. For the past few year, scientist and researchers have been trying to find the solution to overcome this problem. They developed various type solar dryer for drying applications evaluated outcomes revealed that drying process is quite simple, less costly and product are dried under hygienic environment. Solar drying helps to retain the quality of product by reducing its mass and volume which helps in good packaging of these products for their beter mobility.

Now days, there are different type of solar dryer technology are used for drying that are open sun drying greenhouse dryer direct solar dryer, indirect solar dryer, mixed mode solar dryer, dryer with thermal energy storage, natural convection and forced convection dryer. Indirect and tunnel dryer are very much convenient as the product are not good under direct solar radiation and better controlled condition. There are number of factor that affect solar drying process solar irradiance and temperature, performance of solar collector, effect of air velocity etc. Thermal energy storage system also used with new design solar dryer which help to raise the temperature range and time duration for drying. But this technologies increase the initial investment. So that these system are much useful for industrial purpose but not much effectively used by farmer.

Energy gain from sun is carbon free energy now days, every govt. and productive house in the world is finding the ways to reduce the greenhouse gases emission in their operation therefore thy shift install and use

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renewable energy instead of that commercial fuel. Generally solar energy categories in two type of group: used for the generation of electricity other in thermal energy application which include solar drying.

The solar drying application in industrial sector is increasing day to day use for different materials like biomass, brick, cement, textile, polymer, paper, dry fruit, and also for other purpose like waste water treatment etc. the amount of energy consumption is depends which product is dried, by the use of solar dryer is reduced the economic burden. One disadvantage of solar drying is the unavailability of sun is unpredictable and not available during night. Thus hybrid solar dryer are comes with alternate energy source such as auxiliary electric heater, thermal energy, biomass etc.

CLASSIFICATION OF DIFFERENT TYPES OF SOLAR DRYER

a. Open sun drying:

Open sun drying is old and easiest technique also used from ancient time for drying agriculture product. Plastic and metal sheet are used for open sun drying, products are spread over on them directly under the sun light. Sun is uncontrolled energy source and depends on weather conditions. Most of radiation fall on the surface of sheet are get reflected back and amount of radiation absorbed, which are responsible for increase in temperature, are depends on the colure of crops. In open there is too much heat loss in the environment therefore it is not a way to effectively use of sun energy. The disadvantage of deterioration the quality of crops therefore unable to meet the standard of food. It takes much time for drying. Some more limitation of mixing soil, dust, weather condition, effected by rain, birds, insects etc. and also requirement of large area.

Therefore to overcome these limitation researcher developed some much better technique for solar drying. These technique system are more efficient as well as increase the quality of dried products then open sun drying.

b. Direct solar drying:

Direct solar drying is modified type of open sun drying. In this method, either a transparent plastic sheet or mirror is used as cover from top which decrease heat loss to outside of dryer. Simultaneously it provide protection from insects, birds, dust etc. for removal of evaporated water from crops proper ventilation is provided. Air is allowed in dryer from below and carried out most air from top of dryer through opening. It reduce the drying time and drying rate increases. Two main example comes under this categories is box type or cabinet dryer and greenhouse dryer. A box type direct solar dryer is constructed with wooden material (plywood), mirror, frame is made by wood which is well insulated with insulation like rock wool, glass wool, mineral wool, polyurethane etc. mirror is placed slanted in front for trapped maximum radiation. These dryer are provide with either natural flow of air or forced flow using centrifugal fan.

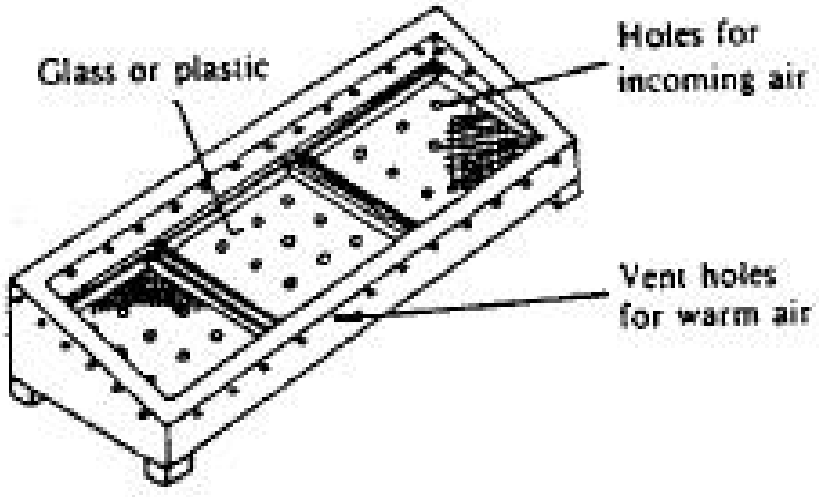

Fig 1. Direct solar dryer [76]

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Zomorodien et.al shows a new method of direct solar dryer i.e. cabinet dryer which dried product using solar radiation as source energy. But with these important feature there is some limitation with this solar dryer like discoloration of corps and reduction in nutritional values. [74]

Al juamily et.al constructed and tested cabinet solar dryer. This dryer has low relative humidity.

c. Indirect type solar dryer:

To overcome drawback of direct solar dryer a modified type of system for drying is used i.e. indirect type solar dryer. These dryer are have high temperature range then direct solar dryer and takes less time for drying. It consist of two different parts, flat plate collector and cabin for drying. Collector has an absorber plate of metal having high thermal conductivity like copper and aluminum and cover with mirror. In this technique, air is heated in collector and crops are stored in drying chamber. Air is allowed to move into the collector through inlet where it is heated and then pass to the drying chamber to reduce the moisture of crops. After pass through crops moist air is moved out from chamber through the exhaust chimney at the top. These dryer are better than direct solar dryer and also prevent crops from direct exposure in solar radiation. Some other advantages of indirect solar drying are higher drying rate, less area required then direct solar drying and nutrient content remains preserve but initial cost is high.

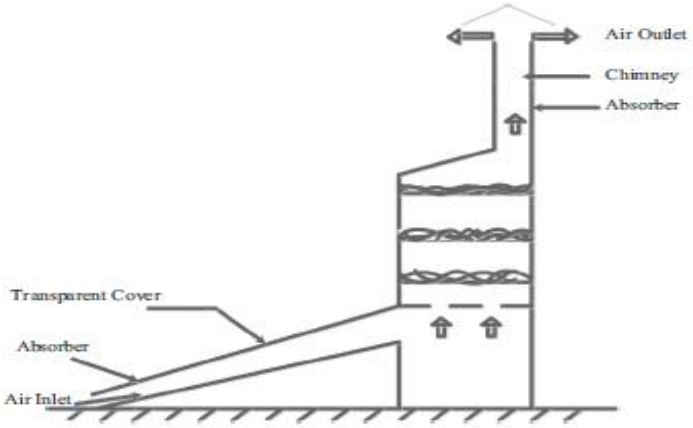

Fig 2. Indirect solar dryer [77]

d. Mixed mode solar dryer:

It is combination two type of solar dryer one is direct solar dryer and indirect solar dryer. In this type solar dryer temperature is raised high in less time and used for product have high moisture content. It is also useful for industrial application like textile cement etc.

This type of solar dryer consist of three parts:-

1. Air heater (with absorber plate optional)
2. Drying chamber
3. Chimney

Like indirect solar dryer air heater receive solar radiation and raised the temperature of incoming air from inlet at the base. Hot air is move upward in the drying chamber where crops to be dried. Drying chamber based on direct solar dryer therefore transparent sheet is used to cover from the top. Drying chamber also receive solar radiation and help in increasing temperature. The hot air passed through the cropsin drying chamber and moved out through chimney at the top of chamber. Air heater is placed on slop angle (at latitude or depends on the location).

Mehdizadeh Zet.al [73] discussed mixed mode dryer for rice drying it was observed that the degree of whiteness was improved then open sun drying and less time is required.

Mixed mode dryer include two different types, first tunnel solar dryer and other cabinet dryer. These types are used for different drying application as per required temperature range for materials.

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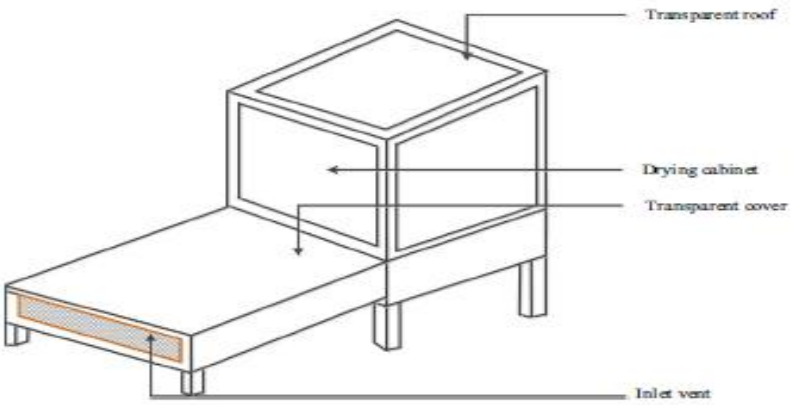

Fig 3. Mixed mode solar dryer [77]

Modified solar dryer:

I. **Hybrid solar dryer**: These dryer are comes with handiness of secondary source for heating other than sun energy. These hybrid solar dryer are also used during night time and bad weather. These system are used auxiliary electric heater, phase change material, backup heating using biomass. These system are always gets importance where continuous heating required. Hybrid solar dryer are great temperature range dryer which supported by secondary source for this. Trays are provided for loading and unloading the material which to be dried.

II. **Solar drying using v-grooved absorber plate:** In this type, black painted absorber plate is shaped v-grooved to increase the heat transfer surface with air. Air is flow from the absorber plate gets conductive heat gain from increased area which help in increment of performance of dryer.

III. **Solar dryers with phase change material (PCM):** Use phase change material increase the time duration for drying. Generally, solid-liquid phase change material are used for this. Solid phase change material absorb heat during day time when sun is available and transform into liquid at its melting point. This stored energy is released out during unavailability of sun. It also help in maintain the constant temperature in solar dryer. Some commonly used PCM is paraffin wax in solar dryer.

IV. **Use of fins with absorber plate**: Fins are provide on the absorber plate with painted black. Fins are also made of same material that used in absorber plate and used for increased the heat transfer with fluid (air). It supports to improve the air temperature for drying and also for increase the time for air inside collector.

LITERATURE REVIEW

Fudholi et.al [62] discussed on open sun drying and other solar drying technology and also compared the drying time reductionwith solar drying technique than open sun drying]. Chabane et.al [63] discussed on heat transfer in new design solar and effect if fins on absorbing plate. [63]. A. A. Elsebaii et.al found that there is noteworthy reduction in period of drying using thermal energy storage material with solar dryer. [64]. O. V.Ekechukwa et.al analyzed the performance of natural circulation solar drying how it can be effected by seasonal weather variation. [65]. MohanrajM. et.al tested indirect forced convection solar dryer hybrid with different PCM. [66]. M. A. Hussain et.al discussed the mixed mode solar tunnel dryer. Products dried in this dryer better in color and quality than in open sun drying. [68]. A.Saleh et.al analyzed modeling and experimental study on a domestic solar dryer. [70]. A. Elkhardraoui et.al experimented on forced convection mixed mode solar greenhouse dryer for red pepper and grapes drying. It was found that the decrease in drying time compared to other present system. [67]. Jain &Tewari experimentally analyzed a natural convective solar dryer with PCM. Study shows that economic and payback period on optimum cost analysis. [71]. C. B. Padhi et.al describe the mixed mode solar dryer with forced convection and also compare the performance of smooth and roughed absorber plate. [68]. A. WaheedDeshmukh et al. conducted experimental investigation to show

the capability of solar dryer to dry ginger safely, employing modeling to obtain the parameters like drying rate, rehydration study etc. and concluded page model to be the best for describing kinetics of ginger.[19].Mingle Lin et al. discussed about contribution of different solar dryer in Chinese medicine drying and its development and application in china. They also informed that collector tube has core importance in drying technology and can be used in direction of future development.[28].Megha S. Sontake et al. reviewed about different method in drying technology and provided comparative study between all and thereby discussing that drying span for mixed mode is less as compared to rest technology.[30].G. Pirasteh et al. reviewed various application of solar dryer. Application from industrial and domestic point of view was considered. Graphical representation of data was also checked. [75].Amina et al. studied the performance of solar dryer with forced convection on two plant material i.e. olive pomance and clocynth for different parameters. Result and discussion were shown graphically as the function of time and concluded diameter also effects the drying time.[74].B K Bala et al installed an active mode solar tunnel dryer for drying of 150 kg pineapple. DC fan used enhanced the drying rate and temperature inside also rise thus attaining 34^0 C – 62^0C for solar radiation variations of 0 to 580 W/m^2.[41].Jan Banout et al. designed double pass solar dryer for drying of bamboo shoots and presented its details. The comparative study of double pass solar dryer, typical conventional dryer and open sun drying and suggested that double pass solar dryer is first on list at performance from every point of view.[45].J. K. Afriyie et al. checked direct mode solar crop dryer dependent on chimney for different orientation, by preparing its laboratory model with replaceable drying chamber roofs. The results achieved demonstrated that rate of air flow can be increased by solar chimney mainly if skillfully designed chamber roof at appropriate angles.[47].

CONCLUSION

This paper gives an overview regarding advancements in different types of solar dryers i.e. the direct, indirect, mixed mode and advancement in solar dryers. The study shows that in order to replace conventional energy based drying methods, solar dryershave been evaluated to be the best option. It is suggested that out of all the available methods, mixed mode solar dryer technology has been found to be better in terms of generated output if properly designed. It has also been concluded that solar drying techniques find their limited use in the industrial sector when compared to agriculture sector. More work need to be done for designing and production aspects for making theseequipments more affordable for farmers.

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