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RECENT TREND IN SOLAR DRYING SYSTEM WITH TEMPERATURE CONTROL UNIT

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ABSTRACT

The solar drying system utilizes solar energy to heat up the air and to dry any food substance loaded, which is beneficial in reducing wastage of agricultural product and helps in the preservation of the agricultural product. Based on the limitations of the natural sun drying e.g. exposure to direct sunlight, liability for pests and rodents lack of proper monitoring, therefore a solar dryer is developed to cater for this limitation. This project presents the design, construction, and working of a solar dryer for food preservation with temperature control system. In the dryer, the heated air from a separate solar collector is passed through plate which is heated by solar energy, and at the same time, the temperature sensors sense the temperature which is inside the area of the heating block and sends data towards the controller. If the temperature is insufficient for drying of food, then controller will start the heater and it will goes on increasing. If temperature goes beyond the temperature of specific food then heater will off automatically and it will save the waste of energy and food from over drying.

***Keywords:* Direct type solar dryer, Forced circulation solar dryer, Indirect type solar dryer, Natural circulation solar dryer, Temperature control unit (TCU).**

I INTRODUCTION

Solar drying is essential for the preservation of food, fruits and vegetables for a long time without affecting their nutrition values. Due to simultaneous heat and mass transfer, the moisture is removed from the product. Drying of agriculture products mainly for vegetables hot air should be in the range of 45-60^{0}C for safe drying. At the moisture content of 25-80^{0}C fungal and bacterial growth increases rapidly. This can deteriorate the product. By reducing the moisture content we can save its nutritional values over long period due to reduction of the contaminants. Solar drying is pollution free method of drying which is main advantage over many fossil fuels. Solar drying is divided into three methods direct sun drying, indirect sun drying, mixed mode sun drying. The drying is done by the air movement in the drying chamber by natural circulation or forced circulation.

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II METHOD OF SOLAR DRYING

2.1 Direct Solar Drying

In the direct type solar dryer, the product is exposed to direct sunlight to remove the moisture content. This method is only suitable for the small capacity product. Directly solar drying has many disadvantages as high labour cost, decrease in quality of product, slow drying rate, reduces the nutrition values of food.

The open sun drying mainly depends on the environmental condition such as solar radiation, wind etc. It usually leads to deterioration of the product because of many demerits such as quantity reduced due to wind, rainfall and other animal impedance. The open sun drying is relatively slow. The direct solar drying is simple in design and it can be manufactured from local materials. It can be manufactured at low cost and also easy to use. The direct sun drying is classified into two types. The outdoor open sun drying through transparent cover which protects the product from rain and other natural phenomena.[1]

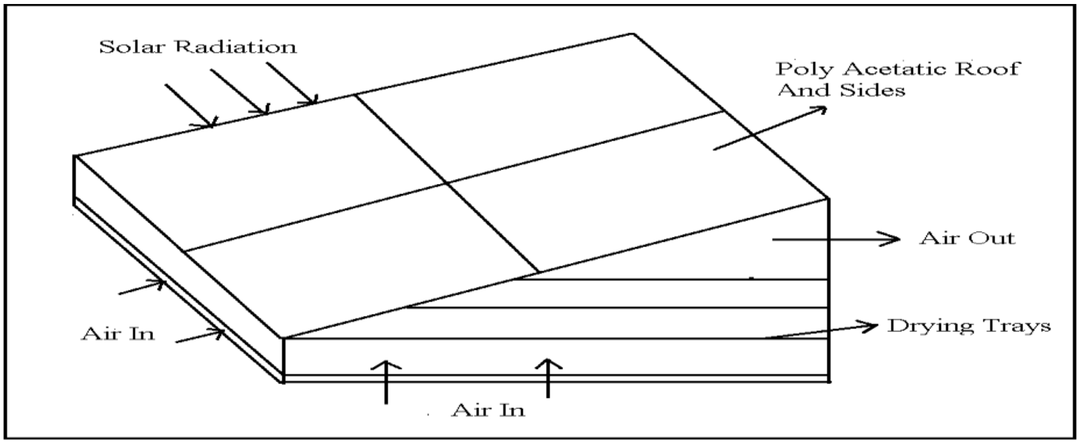

Figure 1 Direct Solar Drying

2.2 Indirect Solar Drying

To overcome the limitations occur in direct sun drying indirect sun drying is developed and tested by various methods. This method is also called as convective solar drying. In indirect solar drying method, the atmospheric air is heated in the flat plate collector. The heating process is either active or passive. This heated air then flows into the cabinet where the product is stored and the moisture from the product is removed by convection. This method mainly used to avoid the direct contact of the sun. This method reduces the disadvantages of direct solar drying. This method has advantages like high drying rate, saves nutritional values of product and product loss is avoided. We can use same dryer for different products.[1]

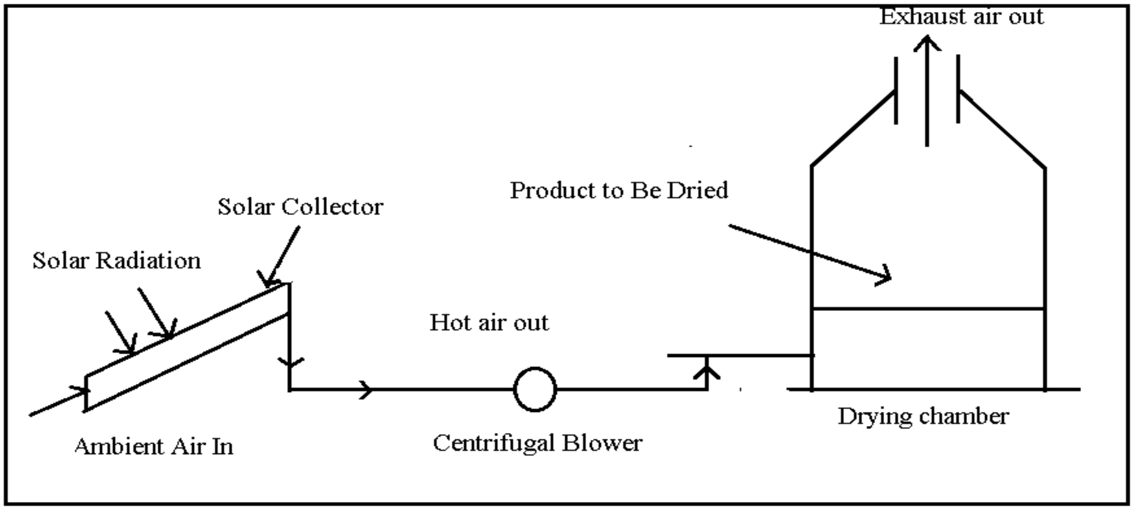

Figure 2 Indirect Solar Drying

2.3 Mixed Mode Solar Drying:

Mixed mode solar dryer is a combination of direct and indirect solar drying. Product may dry by direct exposure of solar radiations and by supplying hot air. The product is dried in this process as convective moisture loss. The drying chamber is totally covered with transparent material to exposure the products to sun.[1]

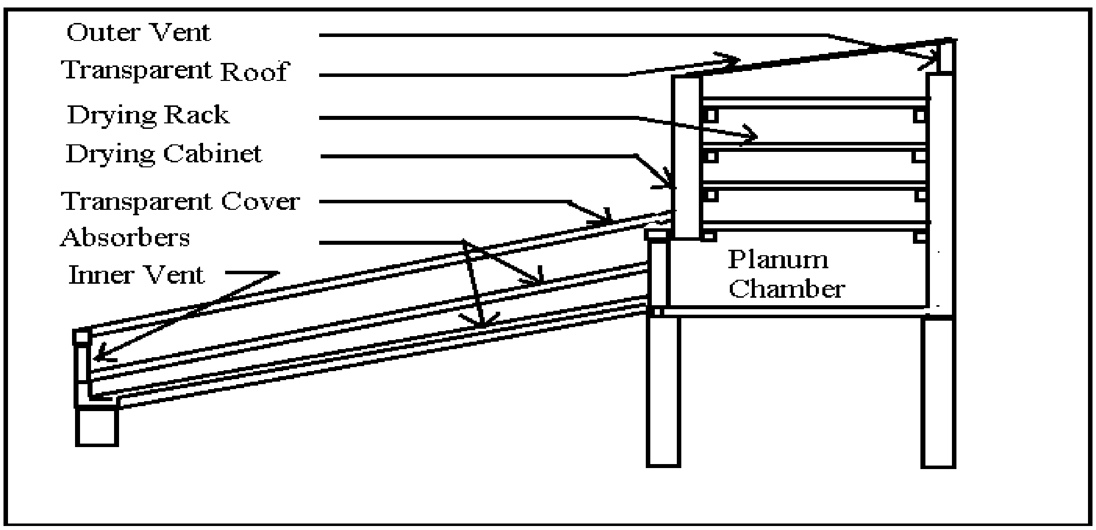

Figure 3 Mixed Mode Solar Dryer

III MATERIALS

The materials used for the construction of solar dryer are given as

Wood is the casing of entire system and it is selected because it is available cheaply and it is the good insulator. Glass is used as solar collector cover and cover for the drying chamber. It allows the solar radiations into the system and resists the flow of heat energy out of the system. Mild steel 1mm thickness and aluminium painted black plate is used to increase the solar radiation absorption capacity. Wooden frames are used for constructing trays. Glues and nails used as adhesive and fasteners. Insect net is prevent insects from entering into the system. Hinges and bundle are used for supporting dryer door.[4]

IV METHODOLOGY

4.1 Construction of Solar Dryer:

The materials used for developing the mixed mode solar dryer are easily available at very cheaply in a local market. The solar dryer consist of collector, air heater, drying cabinet, trays, fan and temperature control unit(TCU).

4.2 Solar Dryer Components:

4.2.1 Drying cabinet: The material used for constructing the drying cabinet is wood. Drying cabinet consists of three plates which are made up of wood. The wood is chosen for cabinet because the wood is very poor heat conductor and the surface finishing of the wood is also very good. It also reduces the loss of radiation.

4.2.2 Cover plate: The common material used for a cover plate is glass, fiberglass or flexible glass. We are use glass for this project as a cover plate. It is a transparent sheet used to cover the absorber plate to prevent dust and rain coming in contact with the absorber.

4.2.3 Absorber plate: This is painted black metal plate kept below the cover to absorb the solar radiation transmitted by a cover plate to heating the air between them. Due to quick response to the absorption of solar radiation the aluminium is used. Copper is also used because it has good ability to keep the absorbed radiation.

4.2.4 Insulation: The insulating material is normally made up of fiberglass, mineral wool, Styrofoam and urethanes. The insulation is used to minimize the heat loss from the system to outside, and it is placed below the absorber plate. The insulator is fire resistant and it can withstand stagnation temperature and it is damaged by moisture or insects.[4]

4.2.5 Temperature Control Unit (TCU): TCU consists of electric heater, temperature sensors, relay and adapter. Temperature sensor which uses to control the temperature of drying chamber, Inlet air and at exhaust. If the temperature is insufficient for drying of food, then controller will start the heater and it will goes on increasing. If temperature goes beyond the temperature of specific food then heater will off automatically and it will save the waste of energy and food from over drying.

4.3 Orientation of Solar Collector:

To receive the maximum solar radiations during a particular season the flat plate solar collector is always tilted at the correct inclination. The best orientation is north and south and south and north direction. The best tilt angle is select according to the local latitude and longitude to obtain the maximum solar radiation. Latitude and longitude of Pune are 18.5204^0N, 73.8567^0E.[5]

4.4 Operation of Dryer:

Figure 4 shows the sectional view of solar dryer. It consists of inlet and outlet port, transparent glass drying cabinet, fan and TCU. The dryer has no moving parts so it is a passive system. It is energized by the solar radiations passing through the collector glazing. The painted black surface inside the surface of the collector is trapped the solar ray's and this trapped energy is used to heat the air inside the collector. Therefore the cooler air enters the system through lower vents and hot air leaves through upper vent. If the dryer contains no items then the incoming air temperature is T_i, relative humidity H_i and the outgoing air temperature T_o, relative humidity H_o. Because $T_o > T_i$ and the dryer contains no items $H_i > H_o$, so the outgoing air picks more moisture as result of the difference between H_i and H_o.[5]

The fan creates pressure difference in the solar dryer. Due to this the air is flows from inlet port to the outlet port. The radiation from the sun incident on the glass and the heat is absorbed by the collector which is place bellow the glass. Due to this heat absorbed by the collector air between the collector and glass is heated. The green house effects achieved in the collector drives the air flow through the drying chamber. This heated air passed through the drying cabinet. This hot air use to remove the moisture content from the food product in the drying cabinet. The removal of moisture content takes place from food product to the surface and surface to the air.

The temperature control unit has important role in solar dryer. It contains the temperature and humidity sensor which sense the temperature and humidity inside the solar dryer. Based on the different food product we can control the temperature and humidity inside the dryer. If the temperature is insufficient for drying of food, then controller will start the heater and it will goes on increasing. If temperature goes beyond the temperature of specific food then heater will off automatically and it will save the waste of energy and food from over drying.

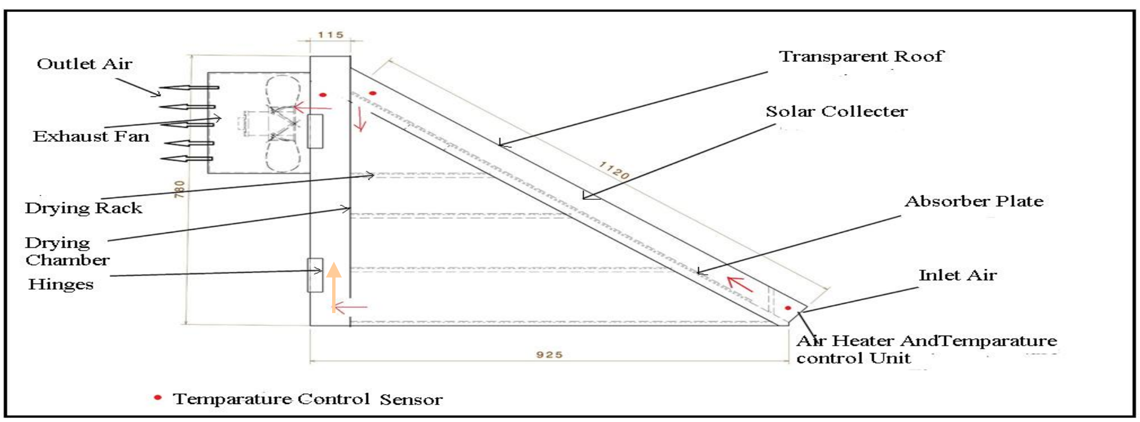

Figure 4 Solar Dryer Layout

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V DESIGN CALCULATIONS

5.1 Energy balance on the absorber:

By equating total heat gained to total heat lost by the absorber of the solar collector we can obtain energy balance on the absorber

$$IA = Q_U + Q_{cond} + Q_{conv} + Q_R + Q_\rho$$ (Bolaji 2008)[4]

By combining three heat losses terms Q_{cond}, Q_{conv}, Q_R the one term is formed (Q_L)

$$Q_L = Q_{cond} + Q_{conv} + Q_R$$

If transmittance of top glazing is τ and total solar radiation incident on the top surface is I_T, therefore,

$$IA_C = \tau I_T A_C$$

The following equation gives the reflected energy from the absorber:

$$Q_\rho = \rho \tau I_T A_C$$ (Bolaji, 2008)[4]

5.2 The angle of tilt of solar collector:

The following formula is given below to find the angle of tilt of solar collector

$$\beta = 10 + lat\phi$$ [4]

Where latϕ is the location of the place where the collector is placed. The latitude of Pune is the location where the solar dryer is designed is 18.520

Hence, the suitable angle of tilt used for the collector is

$$\beta = 10 + 18.52 = 28.52$$

5.3 Isolation on collector surface area:

The average solar radiation on a horizontal surface is 5.75 Kwh/m^2/day. The average effective ratio of solar radiation on a tilted surface to average solar radiation on a horizontal surface is 1.26

Thus, isolation on a collector surface is

$$I = HT = HR = 5.75*1.26 = 7.2 Kwh/m^2/day$$

5.4 Determination of base insulator thickness of collector:

The thickness of insulation is taken 10 mm for the design. The loss through the side of the collector is negligible because the side of the collector is made of wood.

5.5 Collector efficiency:

$$\eta = \rho C_P \Delta V / A_C$$ [3]

5.6 Dryer efficiency:

$$\eta_d = ML / I_C A_T$$ [3]

5.7 Moisture content:

$$M.C = (Mi - Mf)/Mi \quad [3]$$

5.8 Moisture loss ML:

$$M.L = (Mi - Mf)/g \quad [3]$$

VI CONCLUSION

The solar dryer can raise the ambient air temperature to a considerable high value for increasing the drying rate of agricultural crops. The product inside the dryer requires fewer attentions, like attack of the product by rain or pest (both human and animals), compared with those in the open sun drying. It can be used in all season, also used in fewer sunlight areas. It requires less time to remove moisture content when air heater and temperature control unit is used. The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

VII ABBREVIATIONS

I = rate of total radiation incident on the absorber surface (Wm^2)

Ac = collector area (m^2)

Q_u = rate of useful energy collected by the air (W)

Q_{cond} = rate of conduction losses from the absorber (W)

Q_{conv} = rate of convective losses from the absorber (W)

Q_R = rate of long wave re-radiation from the absorber (W)

Q_ρ = rate of reflection losses from the absorber (W).

τ =transmittance of top glazing

I_T=total solar radiation incident on the top surface

β=angle of tilt of solar collector

lat ϕ= location of the place where the collector is placed

ρ= density of air (Kg/m^3)

I_c= isolation on the collector

Δ= temperature elevation

C_p=specific heat capacity of air at constant pressure (J/kg K)

V= volumetric flow rate (m^3/s)

M= mass of crop

L= latent heat of vaporization of water

t = time for drying

M_i= mass of sample before drying

M_f= mass of same after drying

η_d= dryer efficiency

H= the average solar radiation on a horizontal surface

R= the average effective ratio of solar radiation on a tilted surface to average solar radiation on a horizontal surface

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