Performance Evaluation of Single Pass & Double Pass Solar Dryer

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Abstract- *The solar drying system uses the solar energy to heat up air and to dry any food substance loaded, which benefits in reducing wastages of agricultural product and preservation of foods. This paper involves a performance evaluation study on comparison of single pass and double pass solar dryer. The aim is to analyze the efficiency of the single pass dryer is over to the double pass dryer. That smooth plate double pass solar air heater is 3-4% more efficient than the single pass solar air heater. This types of solar air heaters are used to drying the chili, tomatoes, green pepper, onion, carrot, curry leaves, etc.,*

Keywords- solar air heater, single pass, double pass, storage medium.

I. INTRODUCTION

The solar drying is one of the most food preservation techniques. It will used to preserve the food products for longer periods. Drying is the oldest preservation methods of agricultural products. In developing countries, majority of population is engaged in farming activities. Almost 80% of the total food products are cultivated by small farmers. Drying of agricultural products using renewable energy such as solar air heater is eco- friendly and has less environmental impact. Even today, most of the agricultural produce such as grains, spices, fruits, and vegetables are dried under the sun. Whenever, drying these products are directly under the open air has most drawbacks such as(debris, rain, blowing wind, insect infections, human and animal interface etc.). In this drying system different types of solar dryers have been designed and developed.

The two categories are natural convection and forced convection. In a natural convection dryer the air flow is established by buoyancy induced air flow while in forced convection solar dryers the air flow is provided by using the some external forces like (fans, blower, or fossil fuels, etc.). Therefore single pass and double pass solar dryers also under the forced convection methods. So the objective of this review paper new innovations and technologies in forced convection type solar drying and different modifications and techniques applied to them in order to improve their effectiveness.

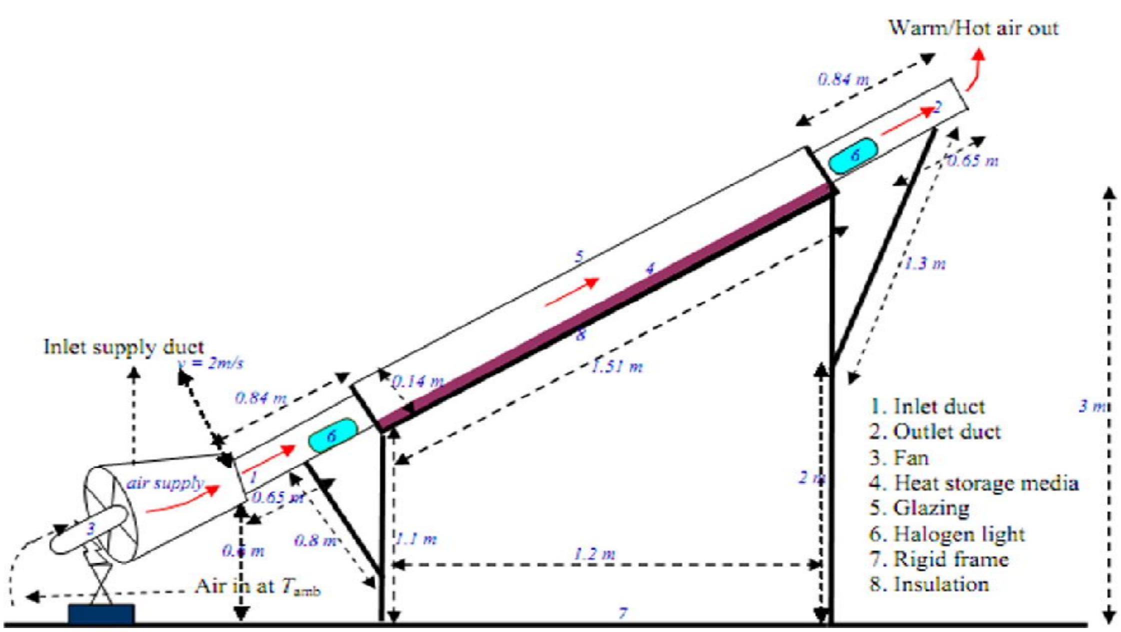

Fig.no.1 solar dryer

Solar air heaters have been found to have a low thermal efficiency because of the low heat transfer coefficient between the absorber plate and air which leads to a high absorber plate temperature and hence a greater heat loss to the surroundings. The flat plate or non-concentrating type collectors absorb the radiation as it is received on the surface of the collector. There are two types of flat plate solar collectors, water heating solar collector and air heating solar collector. The water heating solar collector is more efficient compared to air heating solar collector. Solar air heater is less complicated as compared to solar water heater because it has free from corrosion and freezing. Solar air heater has no need of heat transfer fluid as air is used directly as the working fluid.

SINGLE PASS

This study analysis of a single-pass flat plate solar air collector (SAC) in the case of severe dust deposition surface. Experiments of the SAC with both severe dust deposition surface and clean cover surface are conducted using the steady-state test (SST) method, in order to show a contrast. And the collector characteristic parameters, such as the collector heat removal factor, the collector flow efficiency factor, the total heat loss coefficients, etc. are obtained.

DOUBLE PASS

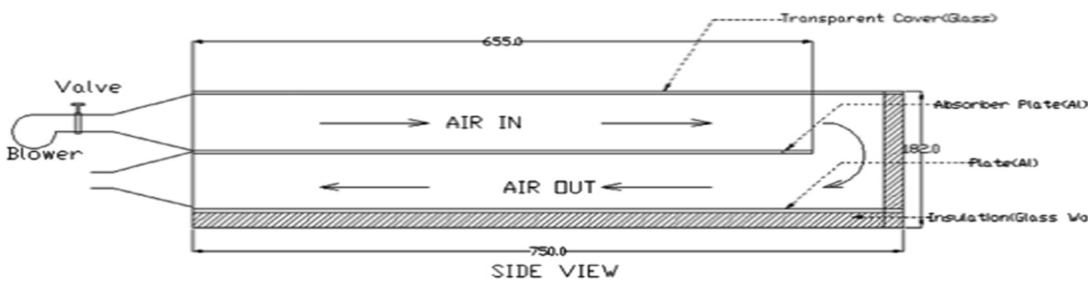

Fig.no.2double pass dryer

Performances of a new designed Double-pass solar drier (DPSD) were compared with those of a typical cabinet drier (CD) and a traditional open-air sun drying for drying of red chili. The drying times (including nights) to reach the desired moisture content of 10% (on a wet basis) were 32 and 73 h respectively. During open-air sun drying the desired moisture content of 10% (on a wet basis) could not be reached even after 93 h of drying (including nights).

II. COMPARING THE ALTERNATIVES

FOSSIL – FUEL DRYERS & SOLAR DRYERS

Primary alternative solar dryers are conventional fuel dryers. A fuel is burned to heat food drying air, the gaseous products of combustion are mixed with the air to achieve the desired temperature. These drying systems are used to around the world no apparent problems, so there is some problems may occur, which allows too much gases into the drying chamber. The advantages that conventional dryers have over solar dryers are that drying can be carried out the days on end, in any kind of weather. In another situation the fuels are burned in conventional dryers may present other problems. Uses of wood may enumerate to problems of deforestation, coal will always cause pollution. These fossil fuels are increasingly expensive but not always available.

ADVANTAGES OF SOLAR DRYER

Solar dryers have the principal advantages of using solar energy a free, available, and limitless energy source that is also non – polluting. Fruits take longer, from 4 to 6 hrs. At temperature ranging from 43 to 63ºC.

- It is faster. Foods can be dried in a shorter amount of time.
- It is more efficient because of the foodstuffs can be dried more quickly; less will be lost to spoilage immediately after harvest.
- It is safer, since foodstuffs are dried in a controlled environment.
- It is healthier.

ENERGY BALANCE EQUATION FOR THE DRYING PROCESS

The total energy required for drying a given quantity of food items can be estimated using the basic energy balance equation for the evaporation of the water (Youcef-Ali, et al. 2004; Bolaji 2005);

$m_w L_v = m_a C_p (T_1 - T_2)$,

Where,

L_v= latentheat (kJ kg^{-1})

m_w= mass of water evaporated from the food item (kg)

m_a= mass of drying air (kg)

T_1 & T_2 = initial and final temperature of the drying air respectively (K)
C_p = Specific heat at constant pressure (kJ kg^{-1} K^{-1}).

THERMAL EFFICIENCY

Qin = G*A (Watt)
G-Incident Radiation (W/m2)
A-Area of the Panel (m2)
Qout = m*Cp*ΔT (Watt)
m- Mass Flow Rate (Kg/s)
Cp- Specific Heat of Water (kJ/kgK)
ΔT- Temperature Difference(K) = (To – Ti)
Ti- Inlet Temperature of Water (oC)
To- Outlet Temperature of Water (oC)
Thermal Efficiency = Qout/Qin (%)
The above formulas are used find the thermal efficiency of the solar air heater for entire readings.

III. LITERATURE REVIEW

NATURAL CONVECTION SOLAR DRYERS

S. Madhlopa *et al*. [1] developed an indirect type natural convection solar dryer integrated with collector storage and biomass-backup heaters. The major components of the dryer were biomass burner (with a rectangular duct and flue gas chimney), collector-storage thermal mass and drying chamber (with a conventional solar chimney). These are tested the dryer in three modes of operation (solar, biomass and solar-biomass) by drying twelve batches of fresh pineapple, with each batch weighing about 20 kg. They concluded that the thermal mass was capable of storing part of the absorbed solar energy and heat from the burner.

Subarna Maiti *et al*. [2] designed and developed an indirect, natural convection batch-type solar dryer fitted with north-south reflectors. They concluded that with the help of reflectors, the collector efficiency without load was enhanced from 40.0% to 58.5% under peak conditions during a typical day. They dried 'papad' –a popular Indian wafer with desired extent of drying (ca.12%, wet basis) which could be achieved within 5 h in this static dryer having 1.8 m^2 area of the collector and computed loading capacity of 3.46 kg. However, they concluded that the design of operation with reflectors may need to be suitably modified as it may cause casehardening in case of certain food items.

K.P. Vijayakumar *et al*. [3] developed and tested a new type of efficient indirect natural convection solar dryer. In this dryer, the product was loaded beneath the absorber plate, which prevented the problem of discoloration due to irradiation by direct sunlight. Two axial flow fans, provided in the air inlet, were used to accelerate and control the drying rate. They loaded the dryer with 4 kg of bitter gourd having an initial moisture content of 95%, and concluded that the final desired moisture content of 5% was achieved within 6 h without losing the product color, while it was 11 h for open sun drying.

FORCED CONVECTION SOLAR DRYERS

S.M. Shalaby *et al*. [5] developed an indirect type solar dryer using PCM as heat storage material for drying medical plants, Ocimum Basilicum and ThevetiaNeriifolia. The model was tested under no load with and without PCM at a wide range of mass flow rates (0.0664-0.2182 kg/s). They found that after using the PCM, temperature of the drying air was higher than ambient temperature by 2.5-7.5 0C after sunset for five hours at least. It is observed that this novel designed successfully maintained in the desired temperature for seven consecutive hours for every day.

R. Velraj *et al*. [6] developed a phase change material based thermal storage system for heating air used in a dryer (Figure-12). They used HS 58, an inorganic salt based phase change material to store excess heat which was then recovered during off sunshine hours. It is observed that at high mass flow rates, the collector efficiency is also higher due to the reduction in heat losses. They also observed that by selection of the phase change material with suitable phase change temperature, avoid heating of air during the peak sunshine hours, thereby ,avoiding the spoilage of food products due to excessive heating. They concluded that by supplying air at lower mass flow rate during the discharging process, maximum capacity of the storage system can be utilized and uniform supply of heat for a longer duration of time during off sunshine hours can be achieved.

Ghatrehsamani S.H. *et al*. [7] developed an indirect type forced circulation solar dryer for apricot drying and compared the results of indirect solar drying with the mixed mode solar drying. It is observed that drying rate of apricots in the mixed-mode is higher than that in the indirect mode of solar drying. Through the application of mathematical model, it was seen that this increase in the drying rate could be due to the values of higher temperature in the mixed mode because of direct solar radiation on product in cabinet in addition to the heated air by solar heaters.

Amina Benhamou *et al*. [8] did a simulation of solar dryer performances with forced convection dryer. The aim of their study was to determine the drying curve and the change rate of drying by solar energy on two plant materials, oliv pomace, and colocynth, depending on solar radiation. Their study allowed them to monitor effects of some parameters influencing solar drying. They concluded that, increasing temperature of drying air, which is most influential parameter leads to increase dhumidity in the dryer and therefore reduced drying time.

V. Shanmugam *et al*. [9] Icorporated a $CaCl_2$based regenerative solid desiccant bed into the dryer for drying green peas. The results of their tests have shown that the integration of desiccant unit with solar dryer continues the drying of products in the off-sunshine hours and improves the quality of drying product. At a given air flow rate of 0.01, 0.02 and 0.03 kg/m^2sec. The product dries to its equilibrium moisture content at about22, 18 and 14 hours, respectively.

Abdul Jabbar N. Khalifa *et al*. [10] investigated the performance of a typical solar drying system and a system equipped with an auxiliary heater as a supplement to the solar heat to dry the beans and peas. They compared the performance of both to that of natural drying. They conducted tests with four different flow rates of 0.0383, 0.05104, 0.0638, and 0.07655m^3/sec. They found that drying times for both beans and peas were reduced from 56 hours for natural drying to 12-14 hours for typical solar drying and 8-9 hours for combined (solar and auxiliary) drying.

S.K. Amedorme *et al*. [11] Designed and constructed a simple and inexpensive forced convection indirect solar dryer for drying moringa leaves. Locally available materials were used in the construction of solar dryer to dry a batch of moringa leaves, 2 kg by mass, with an initial moisture content of 80% wet basis from which1.556 kg of water was required to be removed to have itdried to a desired moisture content of 10% wet basis. The tests about nutritional values of moringa leaves when sun dried and solar dried were not undertaken.

R.K. Aggarwal [12] developed an indirect solar dryer for drying of hill products. The solar dryer of 25kg capacity was attached with a solar cell for running the fan. Bulbs were also provided in the solar collector for heating air during cloudy days, evenings and mornings for faster drying, thereby reducing the drying time.

S. Youcef-Ali *et al*. [13] the effect of airflow turbulence on calorific losses in foodstuff dryers through an indirect forced convection dryer. The drying process is delayed due to various losses through the dryer walls. They also considered the turbulence effect produced due to the flow of air as it is passed over grills. They studied the influence of various losses and presented a comparative study between various models, those that take into account and those that ignore these losses. They used a mathematical model for dryers in forced convection.

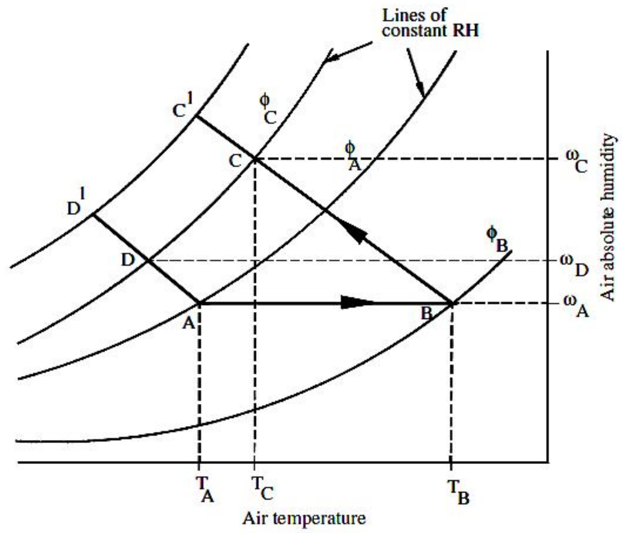

Fig no.3 Representation of Drying Process

IV. RESULT & DISCUSSIONS

THERMAL EFFICIENCY OF THE SOLAR AIR HEATER

The following graphical representation detailed about the mass flow rate of the air and performance of the solar air heater. Here mass flow rate varies from the 0.0212 to 0.0357kg/s. The thermal efficiency will attain from 40-58%. The maximum thermal efficiency attains the mass flow rate of 0.0357kg/s. The readings are taken by the every one hour per day. Mass flow rate varied by the hand blower. Thermal efficiency calculated by one month and chooses to the maximum value. Solar air heater with porous medium (copper scrap) given the maximum efficiency 58%.

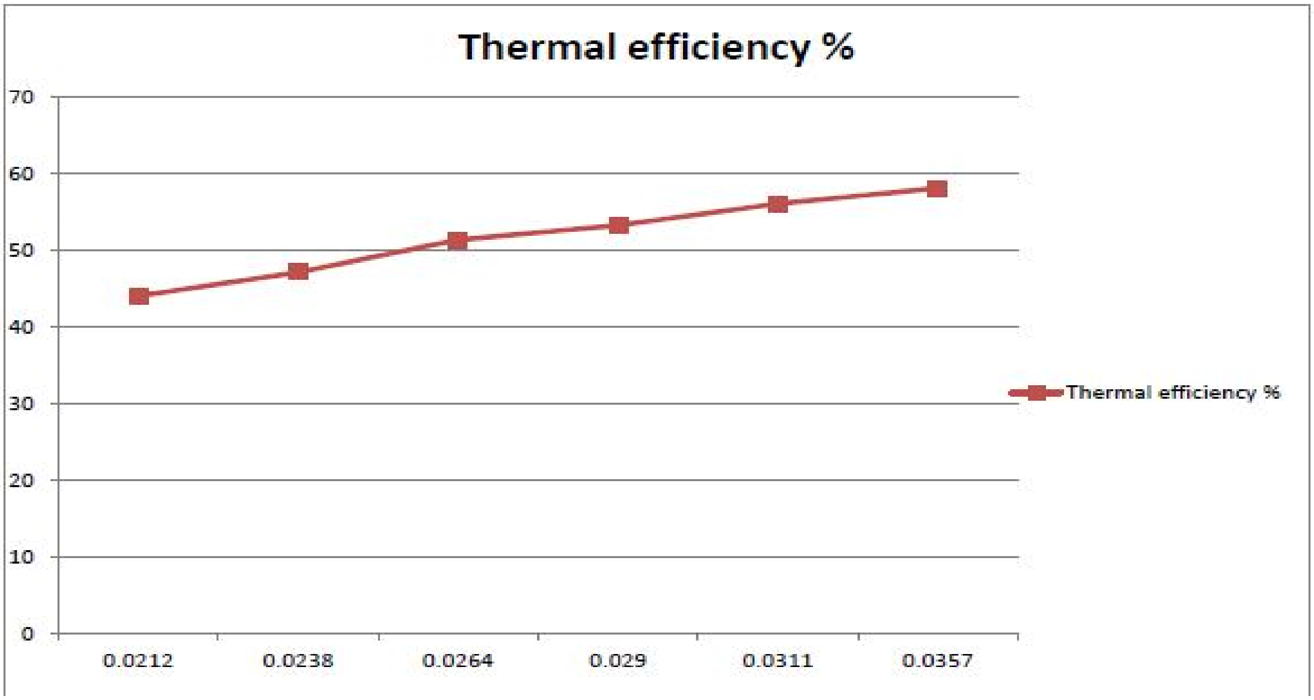

Fig no.4 Thermal efficiency of the solar heater

The results show that, the predicted thermal efficiency in the case of severe dust deposition surface is decreased by 10.7% - 21.0% when the normalized temperature difference ranges from 0 to 0.04. And the optical efficiency of the SAC with severe dust deposition surface is decreased by 8.39% in contrast with the case of clean cover surface.

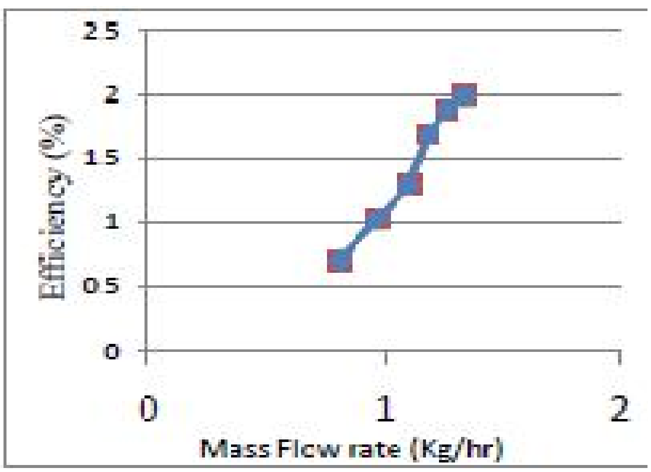

Fig.no.5 efficiency of single pass

The overall drying efficiencies of DPSD to reach the desired moisture content of 10% (on a wet basis) were 24.04% and 11.52% respectively while the overall drying efficiency of Open-air sun drying to reach the desired moisture content of 15% (on a wet basis) was 8.03%. Further, value of the solar dried products from the DPSD was higher than those from open-air sun drying.

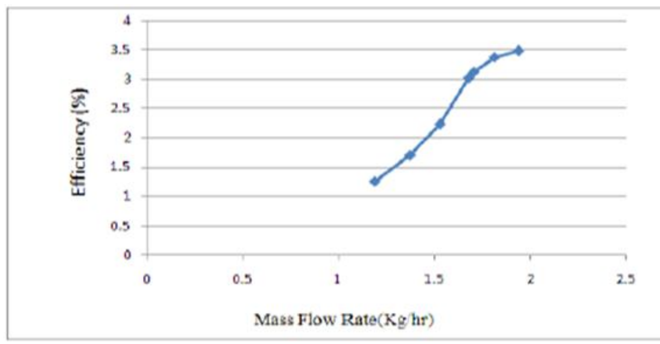

Fig.no.6 efficiency of double pass

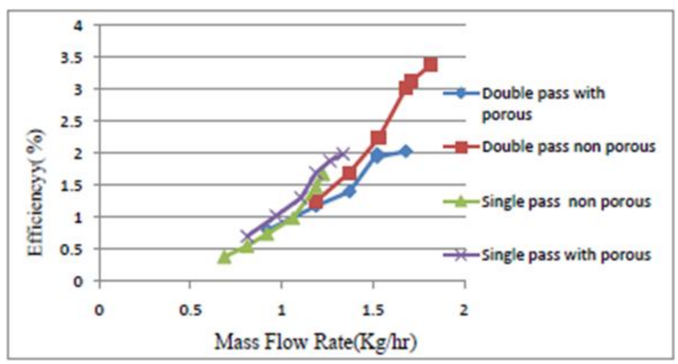

Fig.no.7 efficiency variations with mass flow rate

V. CONCLUSION

This review paper is focused on the available solar dryers systems and new technologies. The author presented a review of various designs, construction details and operational principles of wide variety of theoretically realized designs of solar energy drying systems. The solar air heater with porous medium for different useful and applied application. The demands of the heat are need in the industries and the different application such as crop drying, floor heating, wet cloth drying etc. The solar air heater consist of three major part such as absorber plate, porous medium, air input method (forced convection). A detailed study was conducted to evaluate the performance of the double pass solar air heater with Porous medium (copper scrap). From the experimental results, it was observed that, the solar air heater with copper scrap as energy storage material delivers comparatively high temperature air throughout the day. The double pass solar air heater with copper scrap is the efficient one. The maximum thermal efficiency of this arrangement of double pass solar air heater attain in 58%. Heat transfer in double pass solar air heater system is done by Conduction and radiation respectively

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