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Experimental Analysis in Solar Air Heater Through Modified Absorber Plate

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Abstract

Renewable energy-such as solar, wind, and biofuels can play a key role in creating a clean, reliable energy in future. The benefits are many and varied, including a cleaner environment. Using renewables to replace conventional fossil fuels can prevent the release of pollutants into the atmosphere and help combat global warming. Solar Air Heaters (SAHs) are one of the important thermal energy converting devices which heat the air by converting and transferring the absorbed solar insolation. They are very simple in design, manufacture and easier to maintain and also have three to four times of energy conversion rate compared with solar PV collectors. Even though the system consists of its own merits, the total installed capacity of solar air collectors is only 0.3%. This happens due to that lower thermal efficiency of the Solar Air Heater (SAH) caused by poor heat transfer coefficient between air and absorber plate. To improve the efficiency, various configurations of solar air heaters are analysed. Improvement in the thermal performance of the solar air heater remains as a challenging task for the designers as well as practitioners. With this intension of increasing the heat transfer coefficient in mind, various researchers have conducted tests by artificially inducing turbulence by devising artificial flow modification structures called as turbulators. In this present work adding value to the efficiency improvement to SAH the thermal performance of the solar air heater is improved by a new design incorporating various techniques like modified Tesla valve for the passage of forced heat waves, serpentine duct in absorber plate for carrying heat waves, provision of Fins on the absorber plate with roughness and waviness creation in the passage of forced heat waves. The new configuration is analytically and experimentally investigated and optimized for enhanced efficiency of the solar air heater.

Keywords: **Solar Energy; Absorber plate; Modified Tesla valve; Renewable Energy Integration**.

1. INTRODUCTION

Agricultural products and their drying process are typically used to extend the products' shelf life by eliminating moisture content, which prevents the growth of bacteria, yeast, and mold. The open sun drying method has been utilized for agricultural product drying since ancient times. It takes longer with this technique to get the necessary moisture level in the veggies and grains. The natural wind movement contaminates the vegetable goods throughout the open sun drying process, and part of the items are consumed or taken by the flying birds. To get around this, the vegetable products are dried using a sun dryer that is housed in a closed chamber greenhouse. Over the past three decades, a large number of research studies have been published in the field of solar dryers. Sharma et al. [1] covered the economic analysis of an indirect solar fruit and vegetable dryer in this regard. The internal rates of return and payback period were given. Purohit et al. [2] contrasted the open sun drying method with the economical viability of solar drying based on indirect type. It was claimed that the collector used determined the capital cost. Four types of solar dryers—direct, indirect, mixed mode, and hybrid—were studied by Fudholi et al. [3] based on the product being dried, as well as their technical and financial features. Amer et al. [4] assessed and contrasted the hybrid solar dryer's performance with that of the open sun drying technique. It was discovered that whereas the open sun drying method reduced the moisture to 62%, the hybrid dryer required 8 hours to reduce the moisture from 82% to 18% (wet basis) of 30 kg of ripe banana slices. It was also claimed that solar dryer goods outperform open sun methods in terms of texture, color, and aroma. El-Sebaii and Shalaby [5]

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examined the research on solar dryers and solar air heaters operating in two modes (mixed mode, indirect mode). Further research was recommended in order to enhance the efficiency of solar air heaters equipped with flat, v-corrugated, and finned plate absorbers.

Om Prakash and Anil Kumar [6] gave a thorough analysis of the many solar dryer systems in terms of their construction and functionality. It was proposed that active solar dryers, as opposed to natural convection dryers, are more controllable and effective. It was also suggested that, in order to minimize relying on energy and fossil fuels, photovoltaic-thermal based dryers are recommended for active solar dryers. The convective heat transfer coefficient in an indirect solar drier and an open sun drying method for fenugreek were compared by Vipin Shrivastava and Anil Kumar [7]. It was determined that the measured convective heat transfer coefficient showed how quickly drying was occurring inside the dryer. The many research studies on solar tunnel and green house dryers based on forced and natural convection mode were evaluated by Rajendra Patil and Rupesh Gawande [8]. The experimental study, exergy, and drying kinetics analysis of turmeric in a mixed mode forced convection solar tunnel drier were published by Karthikeyan and Murugavelh [9]. It was reported that it took 12 hours in their designed drier and 43 hours in the open sun drying method to obtain the same final moisture content for turmeric, which had an initial moisture content of 0.779 (kg water/kg dry matter). Using an indirect solar drier, Rachida Ouaabou et al. [10] reported the drying properties of two varieties of Moroccan sweet cherries, namely Burlat and Van. It was claimed that for delicious cherry fruit to dry in 240 minutes, the ideal drying temperature was 80°C and the ideal air velocity was 300 m3/hr. The comparative analysis of the solar air heater flat plate collector's simple and double passes with trapezoidal obstacles was reported by Adnane et al. [11]. Additionally, an experimental investigation was conducted on the drying properties of henna, focusing on the parameters that were influenced by outside settings. The thermal performance of three similar sun tunnel greenhouses with forced convection for peppermint drying was assessed by Morad et al. [12]. With a load of 4 kg/m2 and a flow velocity of 2.10 m3/min, the rate of drying increases from 22.78% to 24.8%. The thermal performance of one-step and three-step solar air collectors for drying cocoa beans was statistically studied by Mendoza Orbegoso et al. [13]. Three-step solar air collectors were shown to have a 67% better thermal efficiency than one-step solar air collectors. The PV-thermal based liquid desiccant-assisted sun drier for drying tomato slices was examined by Mahdiyeh et al. [14]. The results of the research suggested that 60°C and 23% relative humidity be enough to produce dried tomatoes with their desirable properties. It is clear that a great deal of research is being done on solar dryers that dry vegetables using forced and natural convection modes. It is also clear that there is no information about a literature review on drying paddy. As a result, an experimental inquiry was conducted in the current work to dry the paddy grains using modified tesla valve flow passage, and the outcomes were compared with open sun drying.

2. EXPERIMENTAL SET-UP

The experimental investigation is performed in a solar air heater based on forced convection mode as shown in fig 1 and fig 2.

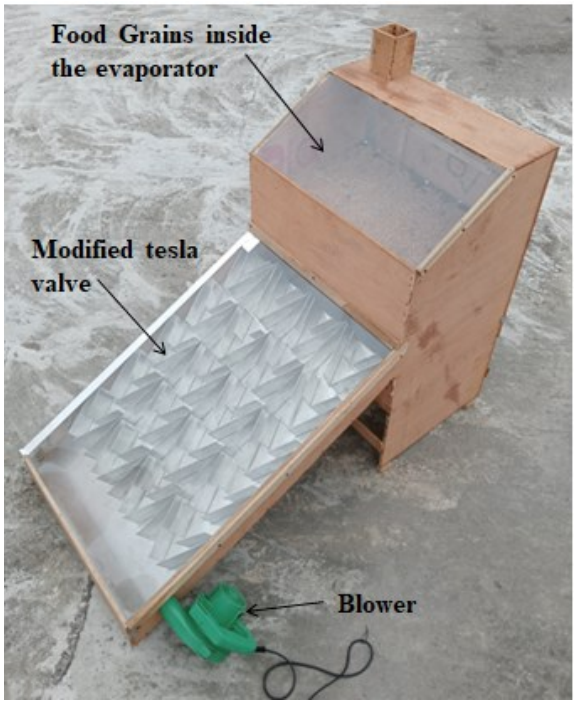

Fig 1. Photograph of modified tesla valve absorber plate in solar air heater

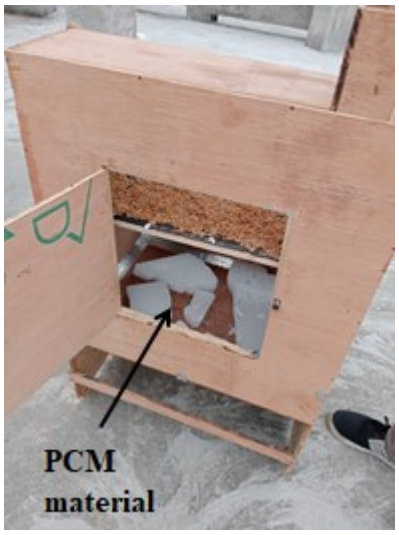

Fig 2 Photograph of Phase change material paraffin wax and paddy grains in solar air heater

A Tesla valve, called a valvar conduit by its inventor, is a fixed-geometry passive check valve. It allows a fluid to flow preferentially in one direction, without moving parts. The device is named after Nikola Tesla. In fig 3.

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Fig. 3 Tesla valve diverging flow

It is a valve conduit where there is two types of flow – Converging & Diverging flow. CONVERGING FLOW: In this flow as the area reduces the velocity will increase along the flow, this velocity increase means that the pressure will drop along the flow. DIVERGING FLOW: In this pressure will increase along the flow this pressure increase is called an adverse pressure gradient condition as pressure increases along the flow. The air particle decelerates along the line and after a particular length flow reversed could occur, this reversal will lead to flow vortices and energy losses. A short diverging flow is a difficult flow to maintain, it offers far more Resistance than a converging flow. Here the flow is getting divided into two parts along with the flow divergence. After this the secondary stream are directed to mix with the primary stream almost in 180 degree angle which results in whirling of the flow. This design will obviously produce more restriction.

In fabrication, aluminium plate and aluminium sheet is used for fabricating tesla valve. Aluminium plate of 5mm thickness is used to fabricate the absorber plate and aluminium sheet of 1mm thickness is used to fabricate the tesla valve. Advantages of Tesla Valve:

- It has no moving parts.
- The reverse flow of air it not possible.
- It reduces the air flow rate which in turn increases the contact period of air and absorbing plate.
- This increase the heat absorbing efficiency.
- A Tesla valve, called a valve conduit by its inventor, is a fixed-geometry passive check valve. It allows a fluid to flow preferentially in one direction, without moving parts.

In order to observe the variation of temperature inside the solar drying chamber, eight T-type thermocouples are used to measure temperature. Among these eight thermocouples, three are used to measure the air temperature inside the dryer and the remaining five are used to measure the surface temperature inside the chamber. Another J-type thermocouple is used to measure the ambient temperature. Global solar radiation are measured by using high quality Hukseflux Pyranometer (SR20-TI, secondary standard (ISO 9060)) is used to measure the global radiation. The sensitivity of the Pyranometer is 14.77× 10^{-6}V/(W/m2).

3. RESULTS AND DISCUSSION

On clear sunny day, experiments were carried out to investigate the reduction of the moisture content of the one kg of paddy in a tailored solar air dryer. Two equal weighted (1000 grams) samples of paddy wetted are taken; one set of samples is placed in the solar dryer and the set of samples are placed for the open sun drying process. The pyranometer readings and eight thermocouples readings including ambient temperature are measured every one hour. The variation of percentage of reduction in the moisture ratio of the paddy with time for both in solar dryer and modified absorber plate solar dryer is shown in Fig.4

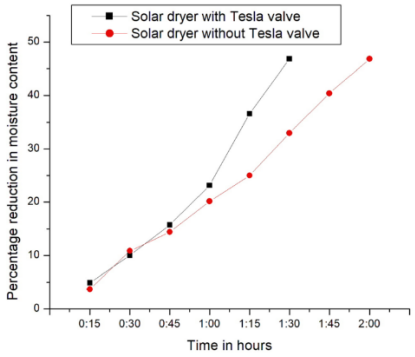

Fig 4. The variation of percentage of reduction in the moisture ratio of the paddy with time for both in flat absorber plate solar dryer and modified absorber plate solar dryer

The experimentation is done in open sun with the forced air to pass through the SAH with the help of blower. The one kg of wet paddy kept inside the solar dryer is monitored for its moisture content for every 15minutes time interval. The percentage reduction in moisture with respect to time compared with solar dryer without tesla valve is plotted in the graph as shown in fig 4. The plots reveal that there is a significant improvement in drying performance of SAH with tailored flow passage and saves time. Thus, the rate of drying in solar dryer is more compare to the open sun drying. The products dried in the solar dryer with modified tesla valve took much less time when compared to the open sun drying method and solar dryer with flat plate collector to achieve the same moisture content. Thus, the developed solar dryer system can be effectively used for the purpose of drying the agricultural products.

CONCLUSION

A solar dryer with modified absorber plate has been constructed and experiments have been conducted to evaluate the percentage reduction of moisture ratio for paddy. SAH with tesla valve absorber plate solar dryer with forced convection, solar dryer was 28.62% more effective when compared to without tesla valve absorber plate drying in case of paddy. The products dried in the solar dryer took much less time when compared to the open sun drying method. The products from the solar dryer were found to be more hygienic. It can be concluded that the drying time depends mainly on air temperature, global radiation, and the mass flow rate of drying air. It is also concluded that the drying rate in the forced convection solar dryer is higher than that of the open sun drying method. Further, extensive studies will be made to investigate the drying characteristics of wet paddy and other different vegetables in the solar dryer while tailoring the heat waves.

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