Construction of a Solar Chimney Dryer and Studying its Drying Potential

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ABSTRACT

There have been many research work presenting various novel types of solar dryers that can be used for drying vegetables, fruits, and other agro-products etc. Solar chimney which consists of a large plate and a centered vertical chimney basically studied for electricity power generation using the draught through the chimney. In this study, it has been demonstrated that the possibility of enhancing the drying process under the plate of a solar chimney due to the draught through the chimney. There is a great potential of using Solar Chimney dryer, drying for industrial, fishery and agro products or raw materials. The advantage is that drying can be done, with the similar rate of sun drying, under the rainy environment obviously with a low drying rate but without destroying quality and protecting them from environmental pollutants.
Keywords: Solar Drying, Solar Dryer

1. INTRODUCTION

Around the world there is a great research interest for alternative energy sources and for enhancing the efficiency of available energy sources. Fossil fuels like natural gas, oil or coal are damaging to the environment and those are non-renewable energy sources. However when searching for a nonpolluting inexhaustible and environmentally friendly energy resources, the solar energy is the best renewable energy source. Solar power plants transform solar radiation into electrical energy. It has the ability to store sufficient energy during the day, so that a supply can be maintained during the night, but the drawback is its low efficiency.

As with so many other inventions, it was Leonardo da Vinci (1452-1519) who created the earliest system, which uses hot air rising in a chimney to drive an apparatus. Isidoro Cabanyes, a Spanish colonel, was the first to propose to use a solar chimney to generate electricity (Cabanyes, 1903). The major player in recent Solar Chimney Power Plant (SCPP) development, the German structural engineering company Schlaich Bergermann and Partners (SBP), designed, built and tested a solar chimney pilot plant in Manzanares, Spain. With its 195 m tall chimney and a 240 m diameter collector this is the largest SCPP to date. At present, there are plans for large-scale SCPPs in Australia, Southern Africa, Brazil and many other places in the sunny areas of the planet [1].

The solar radiation passes through the transparent roof is absorbed by the ground and then emits long-wave radiation; simliar to the process of green-house. As air is heated, it starts to rise up and move towards the chimney, as shown in Fıgure 1.1. Heated air enters the chimney placed at the center of the roof and creates an up draught [2-7].

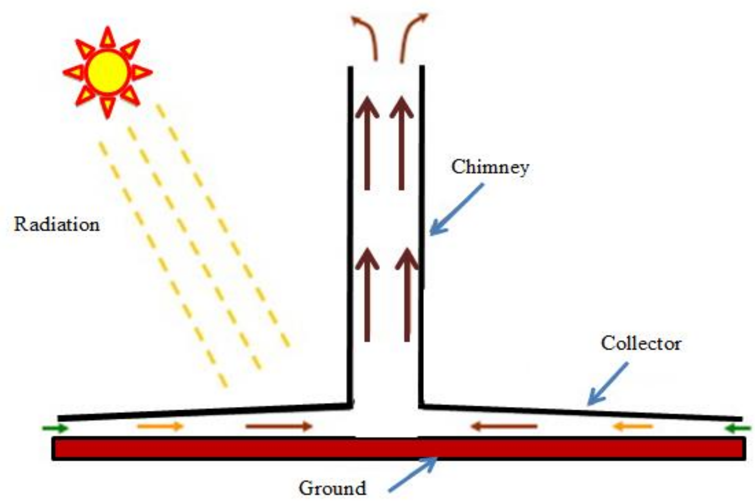


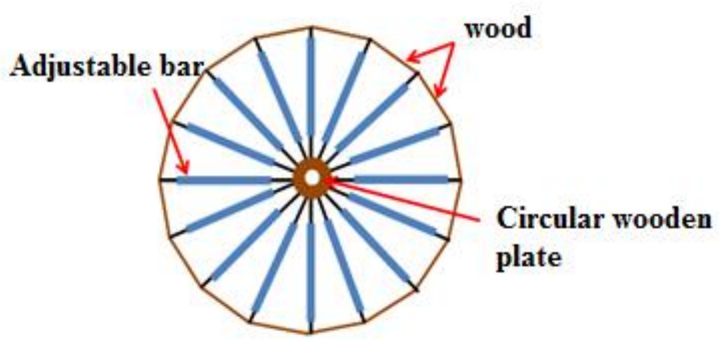
Figure 1: Sketch of a Solar Chimney

Sun drying, drying directly exposing to the sun's radiation, has a very long history. Even in the very ancient era, people around the world used sun drying to dry, vegetables, fruits, fish, meat, etc. In order to increase the drying efficiency, researchers have introduced various types of solar dryers; for drying vegetables, fruits. [8, 9]. The concept behind this research work originated because of the Sri Lankan small scale coir fiber producers who face the problem when sun drying their raw materials because of unexpected rains and unusual raining patterns that occurred during last few years. Objective of this study was to investigate the possibility of drying martials spreading under the flat plate of a small scale solar chimney where the material can be protected from the rain while drying by partially penetrated solar radiation through the transparent plate and enhancing drying process by flushing away the water vapour accumulated on top of the raw material by using the draught established in-side the chimney.

2. EXPERIMENTAL METHOD

The collector of the solar chimney model was designed by using 16 adjustable bars made out of Polyvinyl Chloride (PVC) pipes and wooden rods running inside the pipes. A circular wooden plate with a hole at the center was used to connect another PVC pipe vertically as the chimney. The vertical PVC tube is of two inch diameter and its height could be varied by connecting a similar tube to the free end. One end of the adjustable bar was connected to a centered circular wooden plate and each free end was connected together by wooden strips as shown in the Figure 2. When the centered circular wooden plate is raised upward, length of the adjustable bars self-arranged making an equal angle (collector angle) with the horizontal plane. The plate diameter, ie the length of an adjustable bar is two meters. The collector plate of the solar chimney was covered using transparent polythene and the collector angle could be varied up to 60°.

The speed of the air flow was measured with the accuracy of ±3 % of reading by using an anemometer (Kestrel®2000) which was placed at the neck of the solar chimney. After finding the angle of the collector roof and height of the chimney which gives the maximum flow speed of the air, collector angle and the height, of the model solar chimney were set to those values obtained. Then the material of the collector roof was replaced with glass plates and the surface under the solar chimney was converted to a black surface covering by a black polythene, to study the effect on the air flow speed.



(a)

(b)

Figure 2: (a) Top view of frame of the collector plate (b) Photograph of the constructed chimney dryer

3. RESULT AND DISCUSSION

The initial observations were done in a laboratory using 500 W lamp due to prolonged rainy season experienced during the period of experiment. The variation of the air flow speed with the angle of the collector roof was shown in Figure 3. The maximum air flow speed is observed when the collector angle is 40 ^{o}.

When the height of the chimney is higher the air flow speed is higher as expected according to the previous investigations [1, 2]. However, the height of the chimney had to be limited in this study for 2 m, as initial lab experiments were done for the same height in the laboratory. The maximum air flow speed of 0.054 ± 0.002 m.s^{-1} was observed when the height of the chimney is 2 m.

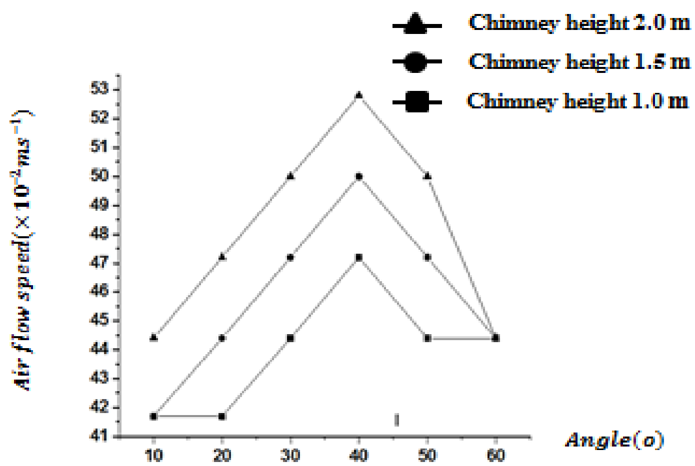


Figure 3: Variation of the air flow speed with the collector angle (lines have been drawn to guide the eye)

After the selecting the optimum design parameters, 40^{o} collector angle and 2 m chimney height, the set-up was installed in the open area with the height of 75 cm from the ground for incident solar radiation to the collector roof (Figure 4.a). The graph (Figure 4.b) shows the variation of the air flow speed during a day through the chimney.

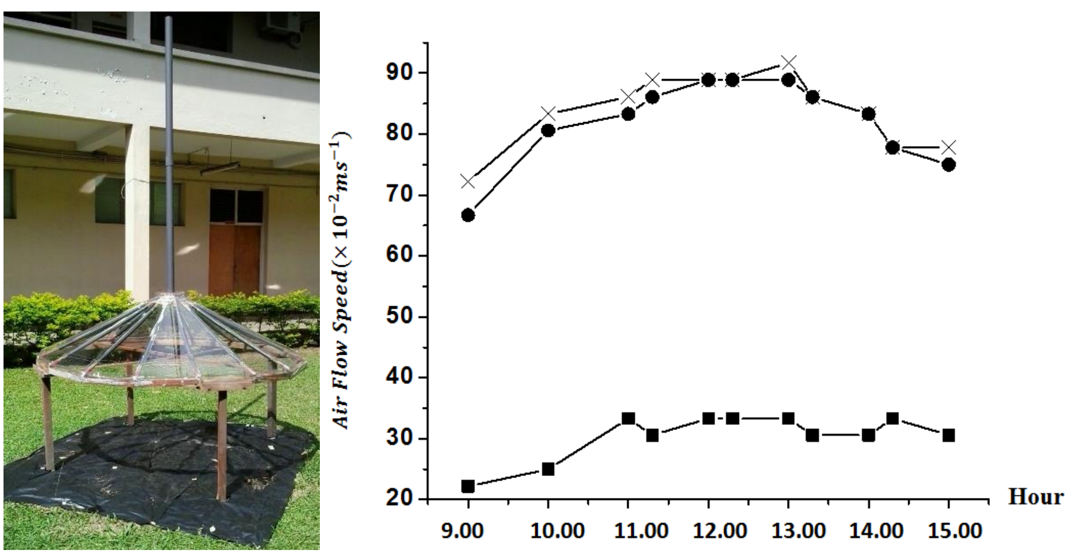


Figure 4: (a) The model chimney dryer in open air (b) Variation of air flow speed (under the collector: ×- Natural flow with grass O- covered by black polythene (■) Variation of the environmental wind speed.

Floor under the collector was covered by a black polythene (figure 4.b) to check whether there is a significant increase in the air flow speed. However, results show that there is no significant increase. Therefore experiment was continued without covering the floor. When compare (Figure 4) with the environmental wind speed there was a significant increase which was more than twice as much inside the chimney.

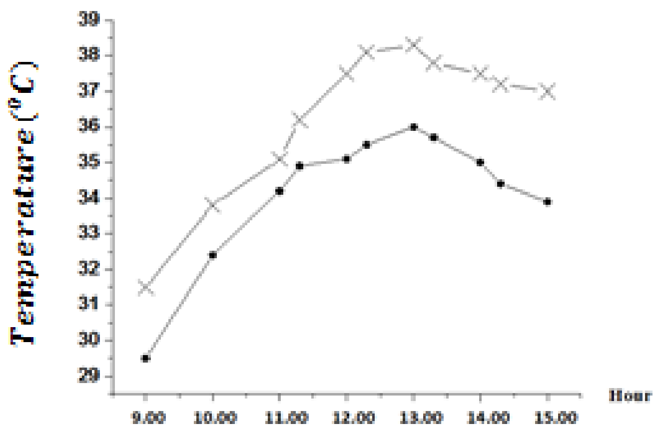


Figure 5: (a) Variation of the inside temperature of the chimney (×) and the environmental temperature (•) during 9.00 -15.00.

Figure 5, shows the variation of the inside temperature of the chimney (×) and the environmental temperature (•). The inside temperature higher than that of the environmental temperature due to greenhouse effect but temperature difference is not very prominent due to the establish wind inside.

Two samples of wet refuse coir (kohubath) with equal masses taken from same wet refuse coir batch (kohubath); in order to make sure that water content is equal. One sample was kept inside and the other sample was kept out-side of the chimney for drying. The areas exposed to the air of the sample were also maintained to be equal by using identical containers. With this scenario, rate of drying is directly proportional to decrease of mass (amount of water evaporation) of the samples. Variation of the mass for both samples is shown in the Figure 6. It is clearly visible from the figure that the rate of drying have no significant difference. Though the material which is inside the chimney, sheltered by a glass plate, can be dried as effectively as a sample directly exposing to sun's radiation. This can be explained by considering the factors that control the evaporation. When water evaporates from the wet refuse of coir, air flow in the chimney flushes the water vapor through the Chimney. For the sample kept outside, though the sample is heated directly by sun's radiation, top of the sample water vapour concentration is higher than that of the sample which is inside. As the environmental wind speed is very low compared to that of inside the chimney (see Figure 4.b), water vapor accumulated over top of the out-side sample, does not flushes away as efficiently as that inside the chimney. High water vapor concentration, over the top of the out-side sample slows down the evaporation process. The amount of energy falling to the sample increase the rate of drying while water vapor concentration around the surrounding decreases the rate of drying. It can be seen that one tends to decrease the rate of dying, compensate by the other tends to increase the rate of dying as a result gives similar rates of dying, inside and outside of the chimney.

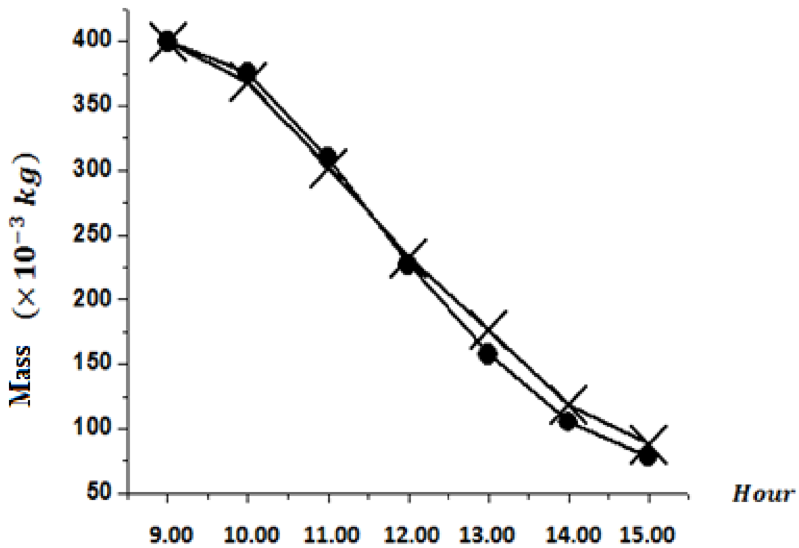


Figure 6: Mass of the refuse coir under solar drying and sun drying ((•) - sun drying (×) - Solar drying)

4. CONCLUSION

This shows that drying can be done under sheltered environment with the efficiency of sun drying. This is very important for small scale industries and farmers. As an example, if a batch of coconut refuse (Kohubath) get exposed rain, it take many more days to dry. If the material is vegetable or fish a whole lot would be destroyed. In that sense, using solar chimney dryer will be safer. Even during a prolonged rainy season such mater can be left inside the chimney for natural drying. The other advantage is when drying foods, vegetable, meat, fish using a solar chimney, they can be protected from environmental pollutants such as dust and bird droppings and therefore quality can be improved.

Further research is needed to get the proper optimum parameters, collector plate area to chimney height ratio, and height to the collector from the ground. Perhaps, drying efficiency of an industrial scale solar chimney dryer with optimum aforementioned parameters, would be higher than the sun drying. However from this primary study, it is very clear that instead of sun drying, a solar chimney dryer can be used and there is no significant difference in drying efficiencies.

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