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Research Article

Comparative Analysis of the Effect of Floor Types and Size Variation on the Performance of Solar Dryer

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Abstract

This research paper present the comparative analysis of four solar dryers with different size and floor types. The solar dryers were used to perform an experiment, the following parameters were read and record for the period of the experiment: temperature, relative humidity and energy. The results of the solar dryers shows that black ceramic floor has higher efficiency compared to white ceramic floor and sandy floor. The hourly variation of temperature inside the dryers was much higher with black ceramic floor compared to white ceramic floor and sandy floor. The solar dryers was observed to have higher energy in black ceramic floor compared to the white ceramic floor and sandy floor. The relative humidity inside the dryer was relatively low in the black floor dryer compared to that of the white ceramic floor and sandy floor. The results of the experiment also shows the effect of size on the solar dryers, when exposed to sunshine it was observed that, the B6 solar dryer gives the highest performance, and the highest temperature recorded inside the dryer was 70°C. At this temperature, the performance efficiency of the B6 dryer was 67%. For B4 solar dryer the highest temperature was 65°C with efficiency of 59% and B3 solar dryer has a temperature of 62°C and an efficiency of 51%. It was also observed that B2 solar dryer which is the smallest among them has a temperature of 58°C and an efficiency of 41.5%.

Keywords

Solar Dryer, Temperature, Efficiency

1. Introduction

Energy is one of the greatest challenges facing the developing countries and Nigeria is not exempted. It is a serious issue that all hands have to be on the desk to see how this can be reduced to the minimal. In line with solving the energy challenges in Nigeria a lot of research is on in the area of renewable energy and solar energy has been found to be very useful as this country is blessed with abundance energy from the sun which if properly harness will improve standard of living, reduce poverty and also reduce deforestation. The trend of total reliance on finite fossil fuels for daily energy demands must change for good; therefore a collective effort is urgently needed to save the environment from climate change caused by acid rain, global warming and other ecological degradations, which have adverse consequences on the environment [9]. Solar energy was the origin of fossil fuels, which became the basis on which the Industrial Revolution was built. These conventional sources of energy, however, will not last forever, and have proven to be one of the main

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sources of environmental problems. Renewable energy sources, such as solar energy, cannot be depleted for all practical purposes. In contrast to fossil fuels they are clean sources of energy and do not pollute the environment during the process of power generation. It is clear that in due time renewable energies will dominate the world's energy System, due to their inherent advantages such as mitigation of climate change, generation of employment and reduction of poverty, as well as increased energy security and supply [11].

Solar energy is one of the main alternative renewable sources of energy crucial to our search for domestic fuel replacements. This is because; it is the source of almost all renewable and non-renewable sources of energy. Also, it is one of the cleanest, it is free from environmental hazards and it is readily available [3]. However, like the development of all other energy sources, the breakthrough of solar energy into the technological world will involve a lot of planning, organization, generation and diffusion of information as well as the provision of infrastructure or devices to harness, it is an efficient and effective means. The total solar power that is incident on the earth's surface from sun is equivalent to 1.5×10^{18} kW h annually, which is equivalent to 1.9×10^{14} ton coal equivalent (Tec). Compared to the annual world consumption of almost 10^{10} Tec, this is a very huge amount and approximately 10,000 times greater than what is consumed on the earth annually [2-4]. On the one hand photovoltaic applications of solar energy have potential to meet electricity demand of world while on the other hand solar thermal applications also have immense potential especially in domestic and industrial sector to meet the global thermal energy demand.

Drying using solar dryers has always been considered a healthy and efficient means of food preservation. Most importantly, solar dried items are healthy and delicious. Outdoor sun drying is best carried out in hot, dry and breezy days [1-5]. Under current drying techniques, solar drying offers a limited but feasible economic alternative to farmers, households and others. The aim of this research is to develop solar dryer with transparent glass and the objectives includes; comparing the effect of the floor variation on the constructed solar dryer and the effect of varying the size on the dryers.

2. Review of Some Related Works

A lot of literatures have been reviewed on solar thermal energy systems, according to Okechukwu and Norton (1999) [7]. Drying is one of the oldest method of food preservation. For several thousand years, people have been preserving dates, figs, apricots, grapes, herbs, potatoes, corn, milk, meat, and fish by drying. Until canning was developed at the end of the 18th century, drying was virtually the only method of food preservation.

Diamante and Munro (2004) [6]. From their research reported that solar drying is still the most widely used method for both domestic and industrial applications. The dried fruits and vegetables are lightweight, do not take up much space and do not require refrigerated storage. Direct sun drying is associated with numerous shortcomings, as products are affected by ultraviolet radiation, dust, rain showers, morning dews, animal and human interference, to mention but a few.

In addition, open sun drying is slow, has no quality control and has a risk of contamination, creating a potential health hazard. The product's quality is seriously degraded, sometimes to the extent that they are inedible.

Hallak *et al*., (1996) [10]. Also carried out an investigation and reported that solar drying has always been considered a healthy and efficient means of food preservation. Most importantly, solar dried items are healthy and delicious. Outdoor sun drying is best carried out in hot, dry and breezy days. Under current drying techniques, solar drying offers a limited but feasible economic alternative to farmers, households and others. Different types of solar dryer are becoming increasingly popular as an alternative drying process for healthy dried food products, for family consumption and in food processing as an enterprise to support livelihood through selling value added products.

3. Methodology

The materials used in constructing the solar dryer were source for within the state and the constructed solar dryer was used to perform an experiment. The experiment was carried out at the University of Ilorin, Physics department. Hourly day time relative humidity and temperature data were read and recorded using hygrometer and digital thermometer respectively. The data were recorded for a period of three months. These months are characterized with higher temperature, lower relative humidity and dusty air because direct solar radiation gets to the earth's surface due to the clear nature of the sky. The performance evaluation of the solar dryers was done. The data were taken with thirty-minute interval between 9 hours to 17 hours Local Time daily. Data generated were used to evaluate energy and efficiency of the dryer.

The efficiency of solar dryer, under different atmospheric condition, is related to dryers temperatures and is given as [8]

$$e = \frac{T_a - T_o}{T_a} \times 100).$$

Where e% is the efficiency, T_a is the air temperature and T_0 is the outlet air temperature from the system.

B2 (0.23m³) B3 (0.77m³)

B4 (1.82m³) B6 (6.12m³)

Figure 1. *(B2-B6): Pictures of the constructed solar dryers.*

4. Result and Discussion

Daytime hourly temperature and relative humidity values were recorded over 103 days to study the variation of temperatures, within the systems and their environment, under different atmospheric conditions, rainy, sunny and cloudy. Figure 2, shows hourly variation of the solar dryers' temperatures under rainy, cloudy and sunning conditions. The plot revealed that the solar dryers has high temperature under a sunning condition, followed by cloudy and rainy condition.

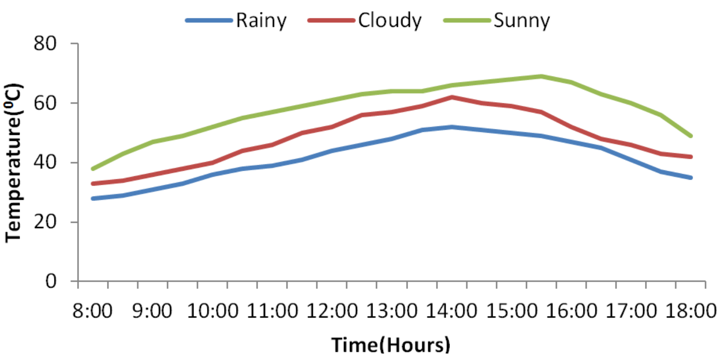


Figure 2. *Daytime Data Plotted with Time.*

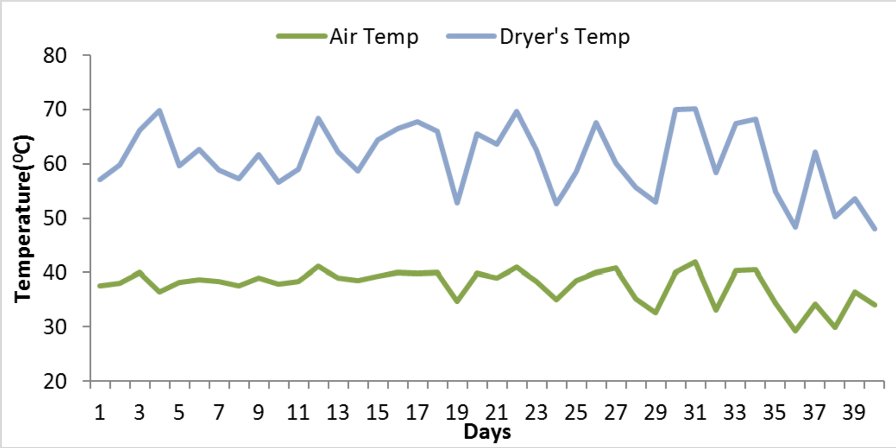


Figure 3. *Average Daily Plots of Dryer's temperature and the ambient temperature over 40 days of investigation.*

Temperature of 40 consecutive days was plotted, Figure 3, shows that the temperature did not change uniformly over the period. The high points on the chart indicate sunning days while the low points are cloudy and rainy days. Figure 4 and figure 5, present the result of the relative humidity of the solar dryer recorded during the experiments.

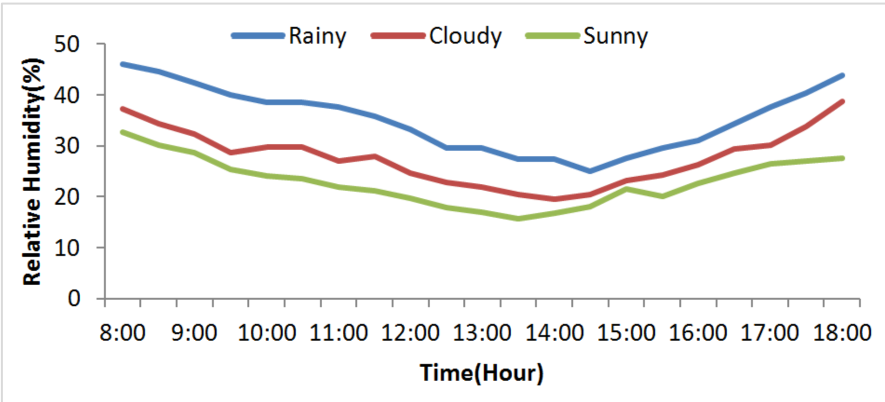


Figure 4. *Daytime Plot for Relative Humidity (%).*

Figure 4, shows hourly variation of the dryer's relative humidity under rainy, cloudy and sunning conditions. The plot revealed that the solar dryer has high relative humidity under rainy and cloudy conditions, followed by sunny condition.

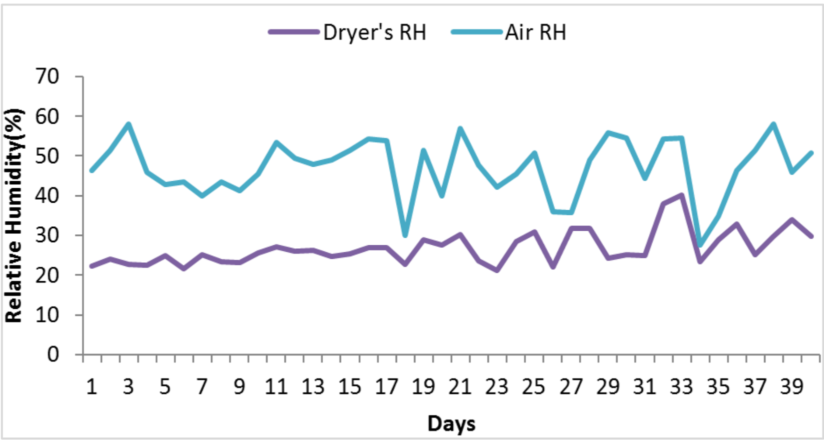


Figure 5. *Average Daily Plots of Dryer's relative humidity and the ambient relative humidity over 40 days of investigation.*

Figure 5, present the relative humidity of the solar dryer's and it shows that it was not changing uniformly over the period. The high points on the chart indicate rainy and cloudy days while the low point is sunny days. Figure 6 and figure 7, present the energy density of the solar dryer.

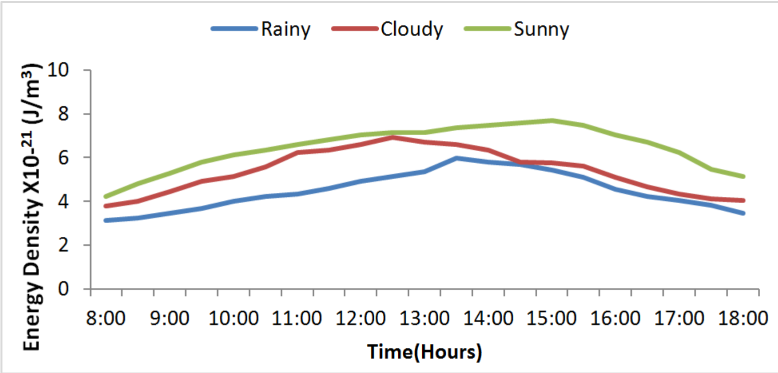


Figure 6. *Daytime Variation of Energy Density.*

The plot, Figure 6, shows hourly variation of the dryer energy density under rainy, cloudy and sunning conditions. The figure revealed also that the solar dryer's has high energy density under sunny condition than under cloudy and rainy conditions.

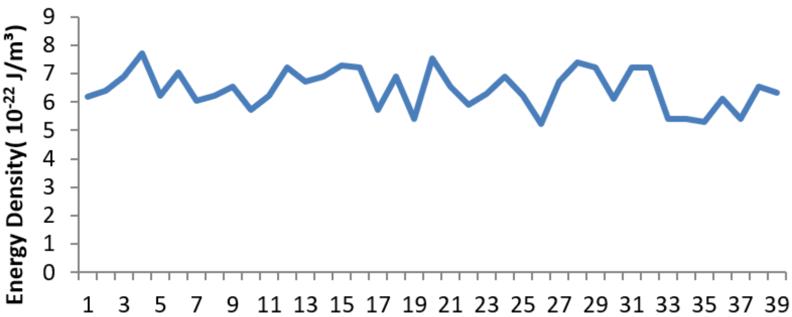


Figure 7. *Average Daily Plots of Dryer's Energy Density.*

Figure 7, shows that the energy density did not change uniformly over the period of investigation. The high points on the chart indicate sunning days while the low points represent that of the cloudy and rainy days.

Figure 8 and figure 9, present the efficiency of the solar dryer.

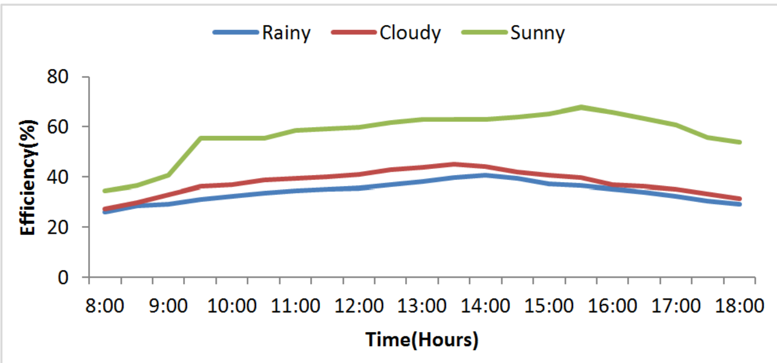


Figure 8. *Daytime Efficiency plotted against Time.*

Figure 8, shows hourly variation of the dryer efficiency under rainy, cloudy and sunning conditions. It also revealed that the solar dryer's has high efficiency under a sunning condition, followed by cloudy and rainy condition.

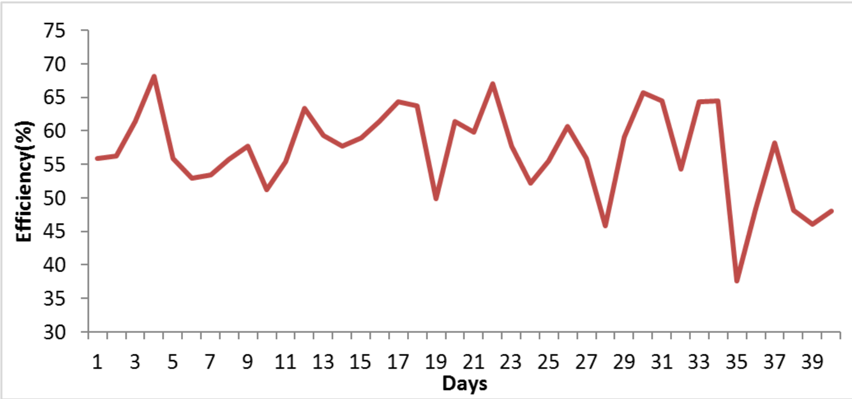
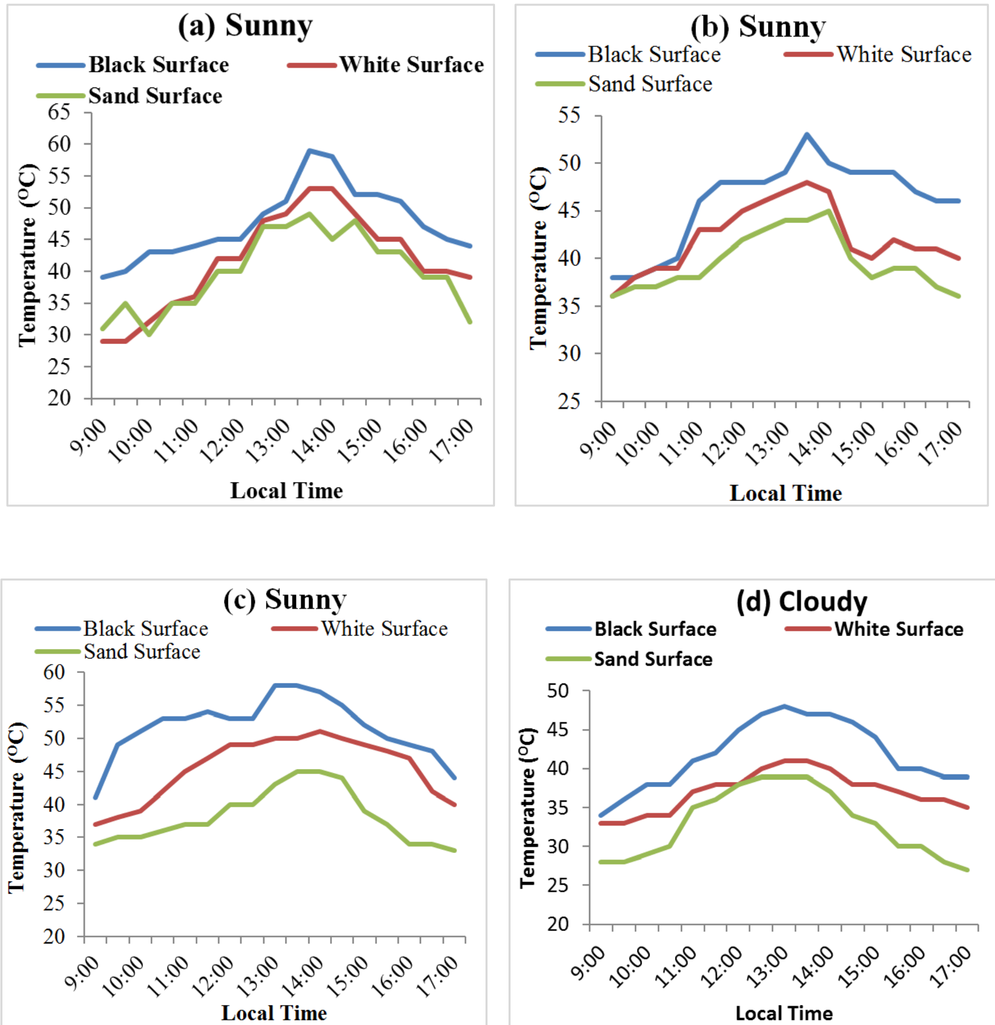


Figure 9. *Average Daily Plots of Dryer's Efficiency.*

Figure 9, present the efficiency of the solar dryer's and it was observed that the efficiency of the dryer's did not change uniformly over the period of the experiment. The high points on the chart indicate sunning days while the low points are for cloudy and rainy days.



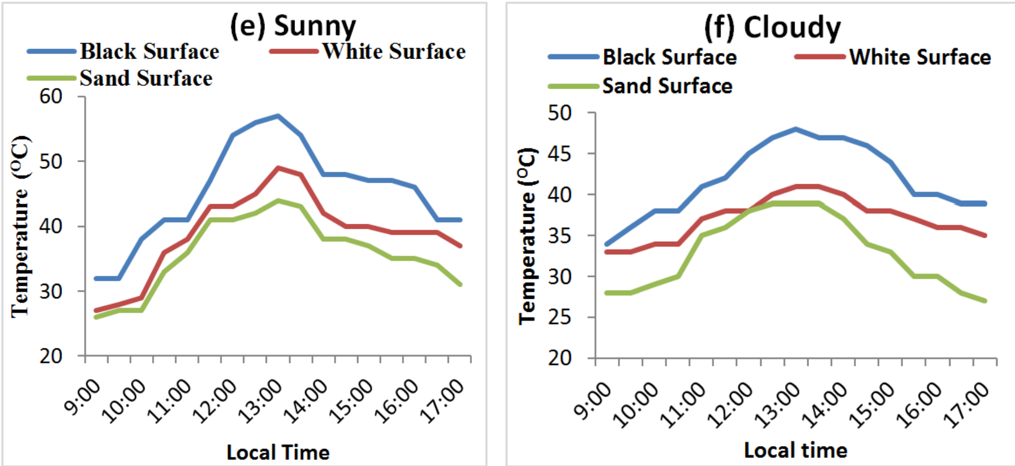


Figure 10. (a-f). Plot of Temperature (°C) against Time (hour).

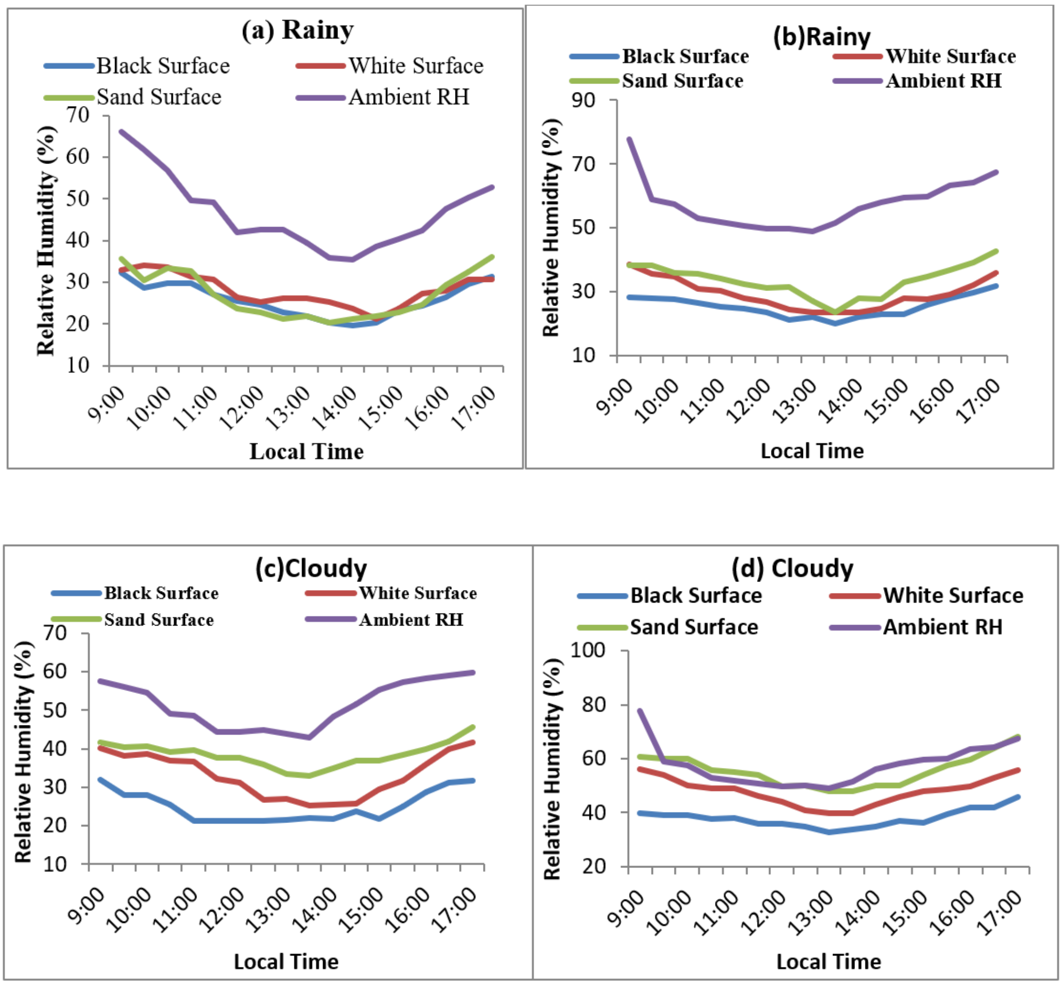


Figure 11. (a-d). Plot of Relative Humidity (%) against Time (hour).

Relative humidity solar dryers with different floor types were presented in Figure 11a to 11d. The relative humidity has its maximum in early hour of the day and its minimum towards the sun-set. The minimum relative humidity was recorded about the middle of the day when the solar radiation was at its peak.

The figure also shows the relative humidity of the dryer's under cloudy atmosphere, sunning and rainy atmosphere. It was observed that the relative humidity was low with black floor compared to white floor and sandy floor, under the same atmospheric conditions.

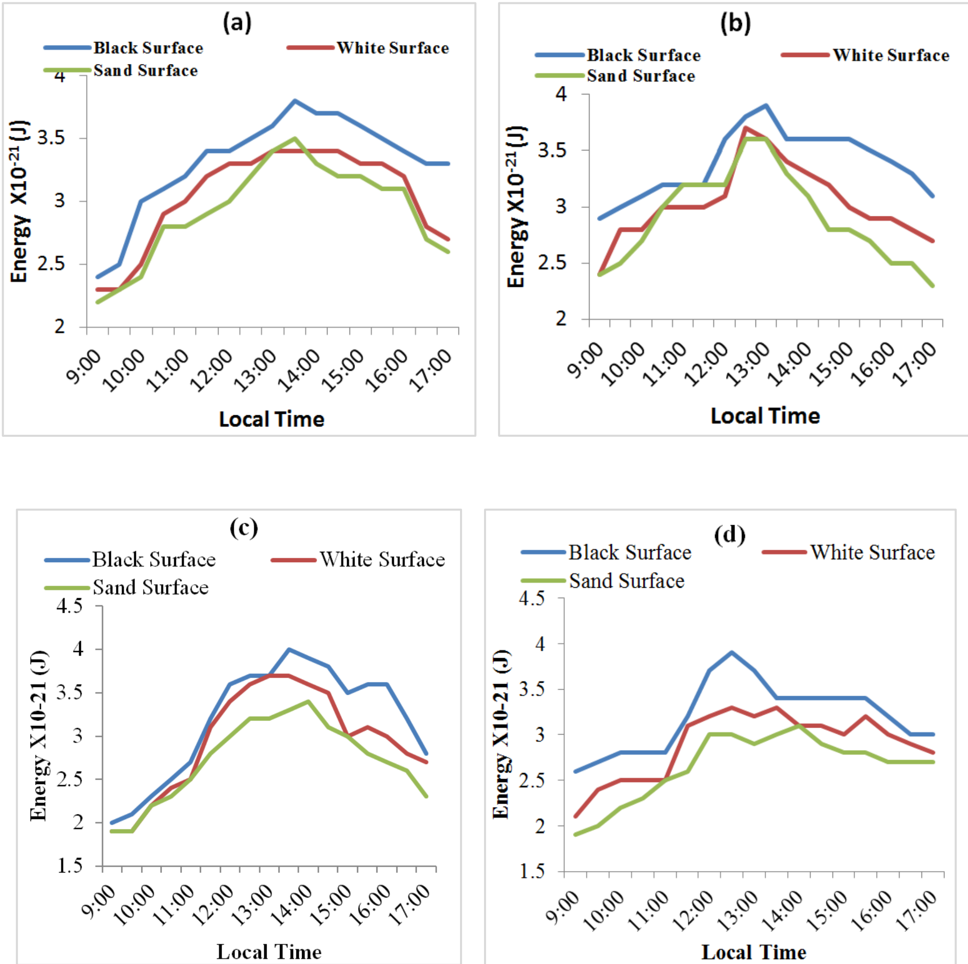


***Figure 12**. (a-d). Plot of Energy (J) against Time (hours).*

Figure 12(a) and 12(b) present the plots of hourly trend in energy of the dryer with floor type. The plots revealed that the trend of the dryer's energy and efficiency was similar under the same atmospheric conditions.

The dryer's energy has its maximum at about the middle of the day when the solar radiation was at its peak. Higher energy was recorded with black floor under sunning and cloudy atmosphere as shown in the figures.

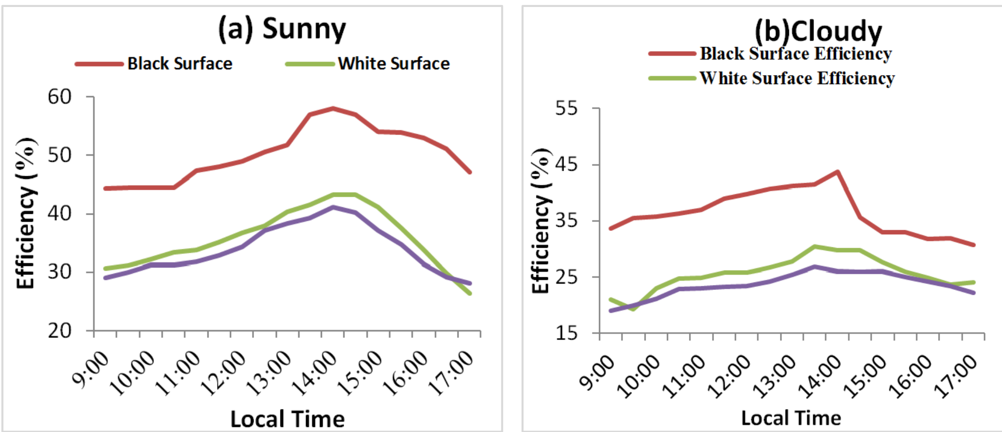


***Figure 13.** (a-b). Efficiency of the dryer with time for sunny and cloudy weather.*

The results show that average air temperature ranged between (24°C-38°C), inside temperatures ranged from, (29.67°C-44.7°C), (31.7°C-49.04°C), (35.39°C-61°C) and (38°C-65°C) for B2, B3, B4, and B6 respectively. It was observed also that the solar dryers has the capability to heat air by (6-20°C) depending on the value of intensity of average daily solar radiation for the period of the experiment. The dryer outlet air temperature was higher than ambient air temperature, indicating prospects for higher drying rates over open sun drying. The solar dryer's performances were compared with each other under the climatic condition of Ilorin, Nigeria. The maximum and minimum temperatures recorded inside the drying chamber were 70°C and 23°C and there corresponding relative humidity are 82.95% and 18.79%.

5. Conclusion

In this research, four solar dryers have been developed to establish the fact that the size and floor type matters when it comes to solar dryers. The effect of size on the solar dryers has shown that the biggest out of the four solar dryer constructed perform better. While the results obtained from varying the floor types showed that when the solar dryer was exposed to solar radiation, the temperature, energy and efficiency of the dryer were higher with black ceramic floor, compared to white ceramic floor and sandy floor.

Abbreviations

e	Efficiency
T_a	Air Temperature
T_o	Outlet Air Temperature
B	The Constructed Solar Dryer

Author Contributions

Serah Omolola Yusuf: Investigation, Writing - review & editing

Taiye Benjamin Ajibola: Supervision

Conflicts of Interest

There are no any conflicts of interest.

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