THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Effects of the Floor Types on the Performance of Solar Dryer

T. B Ajibola
Lecturer, Department of Physics, University of Ilorin, Nigeria
A. J Adeboyejo
M. Sc. Student, Department of Physics, University of Ilorin, Nigeria
S. O Yusuf
Lecturer, Arthur Jarvis University Nigeria
E. Etuh
Lecturer, Arthur Jarvis University, Nigeria

Abstract:
This paper presents the evaluation of the performance of a constructed solar dryer using different floor types (black ceramic floor, white ceramic floor and the sandy floor). The solar dryer was used to perform experiment in which the effect of temperature, relative humidity and energy was observed. The result shows that higher efficiency was recorded with black ceramic floor 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 dryer showed higher energy with black ceramic floor compared to white ceramic floor and sandy floor. The relative humidity inside the dryer was relatively low with black floor compared to white and sandy floor.

Keywords: *Solar Drying, floor type, relative humidity, temperature, energy, performance of the dryer, efficiency*

1. Introduction

Energy is one of the greatest challenges facing mankind in the twenty-first century. With the inception of industrial revolution in the eighteenth century, fossil fuels such as petroleum, natural gas and coal have been the main energy resources for everything vital for human society. However, fossil fuels are being used rapidly by exploration over the years. Also, fossil fuel burning causes damages to the environment [1]. At 4×10^{6} EJ/year, it is 10,000 times the consumption energy in 2007 by the world. The least utilized among various types of renewable energy resources is solar energy [2].

One of the areas of focus in Nigeria is solar radiation because it is abundantly present. The solar radiation received in Nigeria is 7 kw/m^2/day in the far north and 3.5 kw/m^2/day along the latitudes [3]. Giant efforts are being made by various energy centers in the production of energy technology for harnessing of solar energy in Nigeria, since it is located in the high solar radiation part of the world.

Efforts are being made by research centers to popularize the application of solar energy to become household devices. The estimation of Nigeria solar energy with 5 % devices efficiency conversion is 5 X 10^{14}KJ of energy used yearly [4]. This is approximately equal to 258.62 million of barrels of crude oil generated yearly and 4.2 X10^{5} GW hour of electricity generated yearly in the [5].

1.1. The Sun As A Source of Radiation

The Sun which is perfectly spherical is at the center of the Solar System and it is composed of hot plasma interwoven with magnetic force [6]. The sun's diameter is about 1,392,684 km [7]. This is 109 times the diameter of the earth. The mass of the sun is about 1.989 x10^{30} kg. This is 330,000 times the Earth's mass. Element present in the sun are hydrogen, which occupied three quarter of the mass of the sun. The remaining part is mostly helium. The remainder, about 1.69 percent which is equal to 5,600 times the earth's mass composed of oxygen, carbon, iron, neon among others which are heavier elements [8].It takes about 8 minutes and 19 seconds for light radiation to travels from the Sun to the Earth. The radiation from the sun is practically the main source of energy that influences atmospheric motions and many other processes in the atmosphere and on the surface layer of the earth's crust. The radiant energy is emitted from the sun with fairly energy distribution similar to that of an ideal surface at temperature of about 6000 K [9].

As a result of high temperature at the centre of the sun, thermonuclear reaction takes place. Near the sun centre, the temperature is about 10 x10^{6} K. Corresponding movement of matter are so violent that ordered structures of atoms and molecules can no longer be maintained. The nuclei of atom in this region move independently, frequently collide and interact leading to fusion reaction which is believed to be the source of sun energy. The principal source of sun energy is fusion of hydrogen nuclei, which leads to formation of helium.

The fast-moving particles can acquire sufficient energy at high temperature to approach each other and overcome coulomb repulsion at a short range to initiate fusion. This is followed by a change in mass, which is converted to energy. The sun mass is decreasing at the rate of 4 tons per seconds. About two-third of element found on earth have been proved to exist in the sun. The most abundant is hydrogen, which is about 80% of sun's matter. Nearly all the remaining is helium.

1.2. Factors Affecting the Amount of Solar Radiation Reaching the Earth Surface

What brings about the changes in the amount of solar radiation reaching the surface of the earth are changes in the position of the sun, both daily and yearly and changes in the conditions of atmosphere. The amount of solar radiation received at the earth's surface is greatly determined by cloud. As results, the regions with heavy cloud cover receive less solar radiation than the region with weak cloud cover. Therefore, for any region or location, the value of solar energy that reaches the surface of the earth decreases as cloud covers increases [10].

The radiation reaching a particular place relies on the following factors: Sun's distance, period of daily sunlight, inclination of the solar rays to the horizon, how transparent the atmosphere is towards the incoming solar radiation and output of solar radiation.

2. Materials and Methodology

The materials used in the construction of the solar dryer was locally sourced for, black ceramic, white ceramic and sandy floors were used for the floor of the solar dryer.

Figure 1 is a design of solar dryer in which (A) is the complete solar dryer (B) front view of the dryer with holes that allow air inlet (C) is the back view of the dryer with holes that allow hot air to flow out and (D) is the plane view of the cover for both sides and the roof of the dryer.

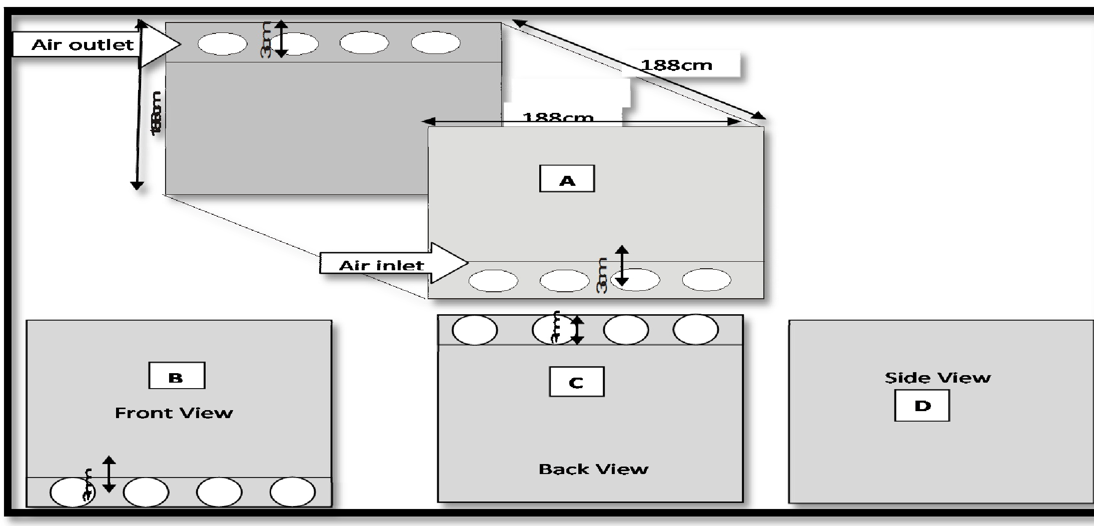

Figure 1: Constructed Solar Dryers

Figure 2: Constructed Solar Dryers

Solar dryer of volume 6.12m^3 was constructed using transparent glass of thickness 4mm, with a refractive index of 1.52. The length, breadth and height of the dryer are 1.83m x 1.83m x 1.83m. Ventilation drilling of 3cm in diameter was made on the glass plane, for air inlet and outlet of the dryer.

Hourly day time relative humidity and temperature data were taken using hygrometer and digital thermometer respectively. The data were taken for a period of three months from November to January. 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 floor types were varied inside the dryer over the periods of 103 day. Black ceramic, white ceramic and sandy floor were used to determine the performance of the dryer for drying purposes. The data were taken thirty-minute interval between 9 hours to 17 hours Local Time daily.

2.1. Measurement Instruments

The temperature and relative humidity measurement were taken for the solar dryer using digital thermometer and hygrometer respectively.

A relative humidity calculator was designed using the visual basic programming IDE. The formula used is shown below,

$$RH(\%) = \frac{W}{W_s} \times 100 \qquad 3.1$$

Where:

$$W = \left[\frac{(T_C - T_{wb})(C_p) - L_v(E_{swb}) \div P}{(T_c - T_{wb})(C_{pv}) - L_v}\right] \qquad 3.2$$

$$and \quad W_s = \frac{E_s}{P} \qquad 3.3$$

W = actual mixing ratio of air

C_P= specific heat of dry air at constant pressure ~ 1.005 J/g

C_{pv} = Specific heat of water vapour at constant pressure ~ 4.186 J/g

L_v = Latent heat of vaporization ~ 2500 J/g

T_c = Air temperature (^{O}C)

T_{wb} = Wet bulb temperature (^{O}C)

E_{swb} = Saturation vapours pressure at the wet bulb temperature (mb)

$$E_{swb} = 6.11 \times 10^{\frac{7.5 \times Twb}{237.7+Twb}} \qquad 3.4$$

P =Atmospheric pressure at surface ~ 1013 mb at sea-level

The wet and dry bulb temperature is input in the calculator and the value of relative humidity is generated in percentage using the designed calculator.

Hourly day time relative humidity and temperature data were taken using hygrometer and digital thermometer respectively. The data were taken for a period of three months from November to January. 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 floor types were varied inside the dryer over the periods of 103 day. Black ceramic, white ceramic and sandy floor were used to determine the performance of the dryer for drying purposes. The data were taken 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 equations used are shown below.

2.1.1. Energy of the Solar Dryer

Photon energy

$$E = hf \qquad 3.5$$

And Wien's Displacement law is given by;

$$\lambda_{max}T = b \qquad 3.6$$

Where E = Energy (J)

h = Planck's constant (6.6 x10^{-34} m^2kg/s)

f = Frequency (Hertz)

$\lambda = Wavelenght(m)$

b = Wien's Displacement constant (2.9 x10^{-3}mk)

T = Temperature of the Dryer (^{O}C)

2.1.2. Performance of the Solar Dryer

The efficiency of solar dryer under different insulation condition as a dependent variable on temperature is given as (Earle, 1983).

$$E\ (\%) = \frac{T_0 - T_a}{T_a} X100 \qquad 3.13$$

Where

E (%) = Efficiency

T_0 = outlet air temperature from the dryer (^{O}C).

T_a = ambient temperature (^{O}C).

Also, efficiency can be determined by using heat content

$$E\ (\%) = \frac{Q_y X M_r}{Q_d T_d} X100 \qquad 3.16$$

Where;

Q_r = heat required to vaporized moisture (KJ/h)

Q_y = heat of vaporization of water (KJ/kg)

Q_d = heat supplied to the dryer (KJ/h)

M_r = the moisture removed (kg)

The moisture content of the drying materials place inside can be calculated using the formula below (www.theravinaproject.org).

$$Moisturecontent = \frac{weightwhenwet - weightwhendry}{weightwhendry} x\ 100 \qquad 3.17$$

A relative humidity calculator was designed using the visual basic programming. The formula used is shown below,

$$RH(\%) = \frac{W}{W_s} \times 100 \qquad 3.1$$

Where:

$$W = \left[\frac{(T_C - T_{wb})(C_p) - L_v(E_{swb}) \div P}{(T_c - T_{wb})(C_{pv}) - L_v}\right] \qquad 3.2$$

$$and \quad W_s = \frac{E_s}{P} \qquad 3.3$$

W = actual mixing ratio of air

C_P= specific heat of dry air at constant pressure ~ 1.005 J/g

C_{pv} = Specific heat of water vapour at constant pressure ~ 4.186 J/g

L_v = Latent heat of vaporization ~ 2500 J/g

T_c = Air temperature (^{O}C)

T_{wb} = Wet bulb temperature (^{O}C)

E_{swb} = Saturation vapours pressure at the wet bulb temperature (mb)

3. Results

Daytime hourly temperature and relative humidity values were taken over 103 days to study the variation of temperature and relative humidity, within the systems and their environment under different atmospheric condition: sunny, cloudy and rainy.

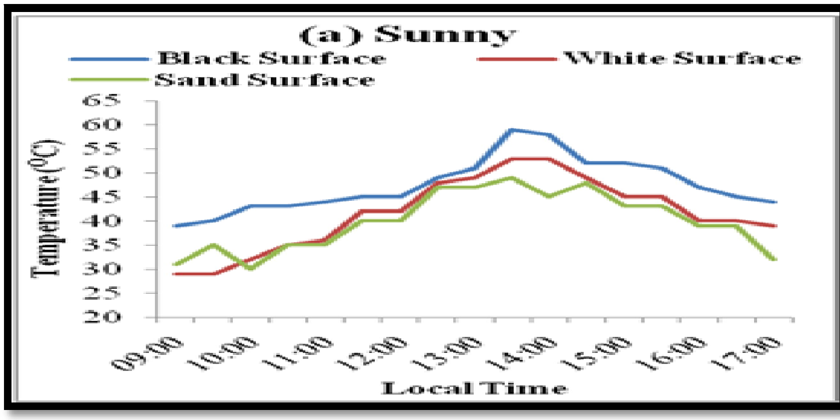

Figure 3

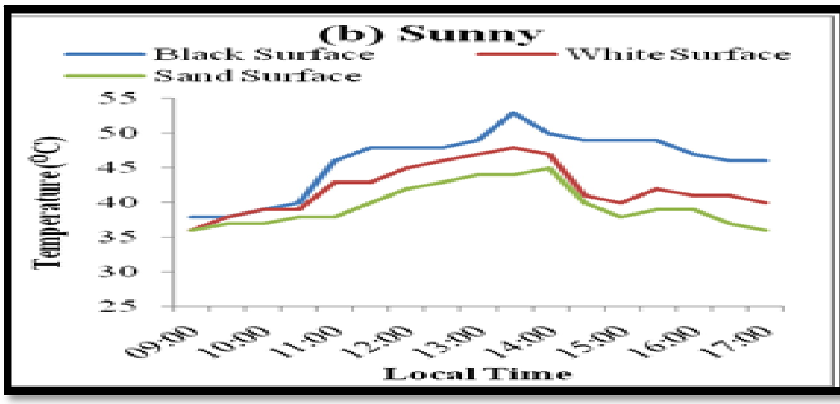

Figure 4

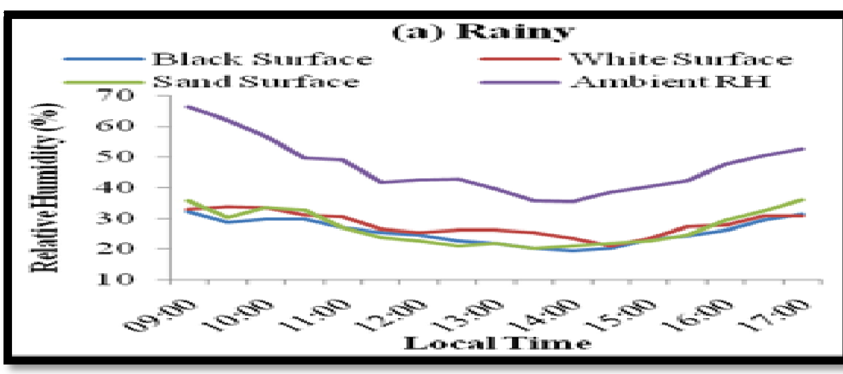

Figure 5

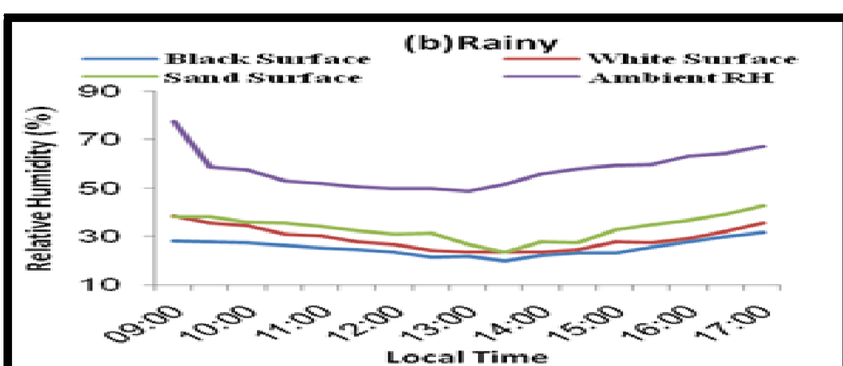

Figure 6

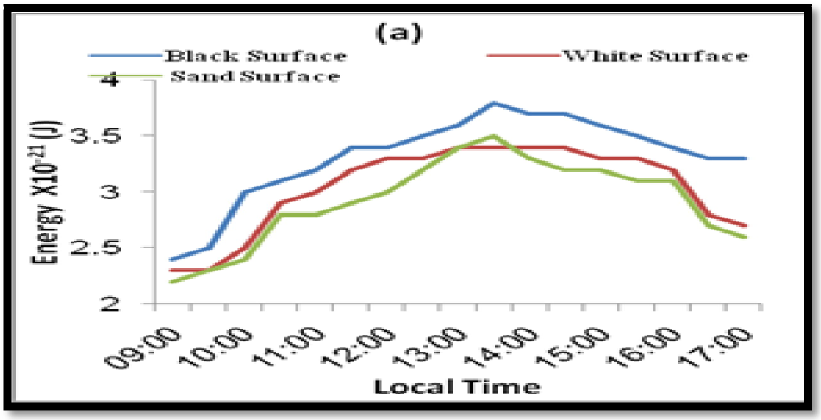

Figure 7

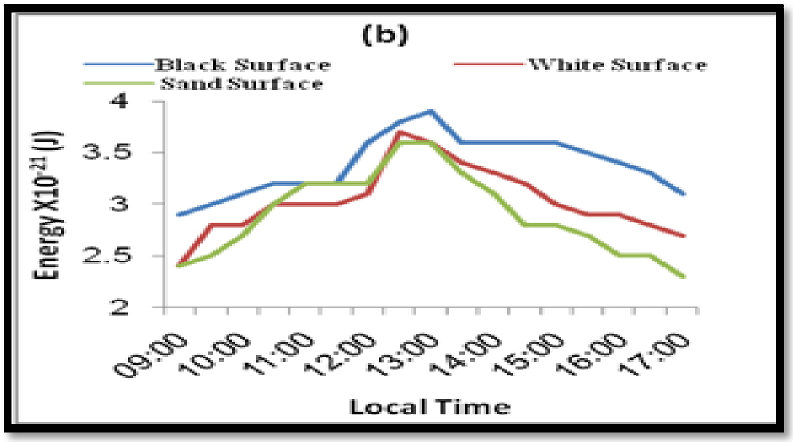

Figure 8

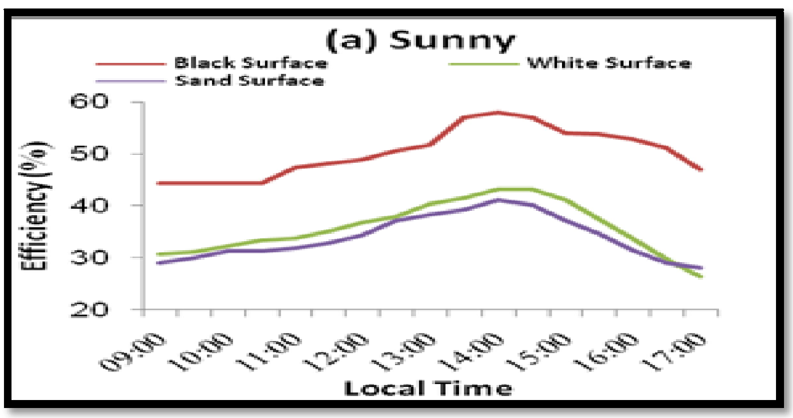

Figure 9

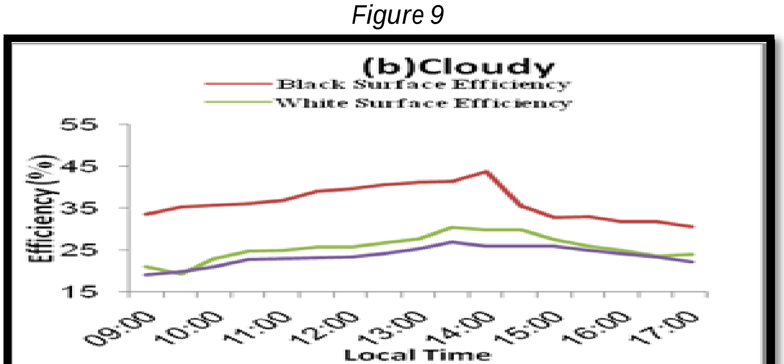

Figure 10

Figure 10 shows the graph of temperature, relative humidity, energy and efficiency of the solar dryers.

4. Discussions

This study has been on performance of direct solar dryer with floor type. Floor effects on few parameters, energy (J), relative humidity (%), and temperature (°C) were also considered.

Examination of the daily performance, energy and temperature of the dryer showed that their values rose from minimum value at about 0900 local time (LT) to reach its maximum about 1400 LT before dropping to another minimum again at about 1700 LT. the maximum efficiency recorded over the period of investigation were 67.98 % with black ceramic floor, 49.33 % with white ceramic floor and 41.11 % with sandy floor.

The maximum energy recorded were 4 X 10^{-21} J for black ceramic floor, 3.7 x 10^{-21} J for white ceramic floor and 3.5 x 10^{-21} J for sandy floor.

The maximum temperature recorded were 59 °C for black ceramic floor, 50 °C for white ceramic floor and 45 °C for sandy floor. The ambient temperature ranged between 40 °C to 28 °C over the period. The plots were well correlated as described by polynomial fit of general equation.

$$y = -ax^2 + bx + c$$

The relative humidity (%) is directly proportional to the water content in the atmosphere. RH is dependent on temperature and the latter is directly proportional to the incident solar radiation on the surface of the earth, hence it varies with time. RH drops down from around 1000 local time (LT) at sunrise to its daily minimum values at about 1400 LT before another rise at about 1600LT. The range RH recorded were 18.78 – 31.34 % for black ceramic floor, 28.45 – 39.89 % for white ceramic floor and 34.78 – 47.35 % for sandy floor. The ambient RH ranged between 41.45 – 62.98 %. Plots of temperature and RH showed that they are inversely related as showed in figure 4.7 (b). The plots were described by a polynomial fit as shown in the figures with strong correlation and of the general formula

$$y = -ax^2 + bx + c$$

From the plots, the high performance of the dryer with black surface was as a result of high absorbtivity of incident energy of the black surface. The black surface absorbed all the incident solar radiation, irrespective of incidence angle or frequency and changed it to heat energy. The heat energy increased the air temperature, of the dryer which is used in drying.

The white surface, a reflective surface reflects the entire incident solar radiation in all direction, thus little heat energy was emitted and available to heat the air temperature inside the dryer.

The sandy surface being a dull surface absorbed almost all the incident solar radiation without re-radiating it. As a result of this, little heat energy is available to heat up the air-temperature inside the dryer.

The results obtained also confirm the established relationship between relative humidity and temperature. The inverse variation of temperature with relative humidity was shown. As the temperature increases, the relative humidity decreases and vice versa.

Furthermore, it was shown that the temperature and RH influenced the performance of the dryer. The increase in solar radiation increased the performance, temperature and energy of the dryer.

5. Conclusion

In this research work, direct solar dryer of volume 6.12 m^3 was constructed using transparent glass. Hourly Relative humidity (%) and temperature (°C) data were taken using hygrometer and digital thermometer respectively. The performance of the dryers was tested with black ceramic, white ceramic and sandy floor under different atmospheric conditions.

The results obtained shows 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. The relative humidity inside the dryer was relatively low with black ceramic floor compared to white ceramic floor and sandy floor. Furthermore, comparative examination shows that the temperature, energy and efficiency of the dryer increased with lower relative humidity. The inverse relationship between temperature and relative humidity was also established in this work.

6. References

i. Bethe, H. A. (1989). Energy Production in Stars. Physical Review, 55(3), 430-434.
ii. Ileoje, O.C. (1997). Potentials for Renewable Energy Application in Nigeria, Energy Commission of Nigeria, 56(3), 5-16.
iii. Onyebuchi, E.I. (1989). Alternative Energy Strategies for the Developing World's Domestic use: A case Study of Nigeria Household's Final Use Patterns and Preferences, Energy Journal, 10(3), 121-138.
iv. Akinbami, J. (2001). Renewable energy resources and Technology in Nigeria: Present situations, Future Prospects and Policy Framework, Mitigation and Adaptation strategies for Global Change. 6(1), 155-181.
v. Falaiye, O.A. (2004). Solar Drying with a Solar Concentrator- Greenhouse enclosure dryer. Nigeria Journal of Pure science, 19(2), 1683-1691, Faculty of Science, University of Ilorin
vi. Emilo, M., Kuhu, J.R., Bush, R.I., Scholl, I.F. (2012). Measuring the solar Radius from Space during the 2003 and 2006 Mercury Transit. The Astrophysical Journal. 750(2), 135-140.
vii. Basu, S., Antia, H.M. (2008). Helioseismology and solar abundances. Physics report. 457 (5), 200-217.

viii. Igbal, M. (1983). An Introduction to Solar Radiation. Academic Press Toronto.
ix. Pidwirny, M. (2006). Atmospheric Effects on Incoming Solar Radiation. Fundamental of Physical Geography, 2nd Edition.