Design, fabrication and testing of solar dryer for drying cassava chip

Muhammadu Masin MUHAMMADU[1] and Adebayo Ekundayo ABRAHAM[2]

Department of Mechanical Engineering,Federal University of Technology, *P.M.B. 65, Minna,Niger State, Nigeria*
muhammadmasin@yahoo.com and ekundayoabraham@yahoo.com

Abstract: In this paper, design and fabrication of a passive integral solar dryer for an export grade cassava chips so as to attain a cassava chips with moisture content of between 12-14% with a higher quality void of bacteria and fungi infection at increased rate of dehydration. This was achieved by analyzing the processes involved in the solar dryer such as the heat and mass transfer within and outside the drying chamber. The maximum temperature of 43.8°C was obtained in the drying chamber which is safe for the grain survival. Performances of the solar dryer depend on air flow rate and solar intensity. An improvement was made to improve the drying efficiency by designing a chimney to increase the buoyancy of air on the dryer, change of Perspex for glass due to its high transmittance value to increase the heat transfer and finally an increase in the inlet region which affect the air flow rate, relative humidity and moisture content. Finally, there is increase in efficiency due to high buoyancy force. And the improvement on the existing dryer has improved and retained the quality of cassava chips for livestock and human consumption. An efficiency of 52% and 48% was achieved in the Solar dryer and open air drying respectively.

[Muhammadu Masin MUHAMMADU and Adebayo Ekundayo ABRAHAM. **Design, fabrication and testing of solar dryer for drying cassava chip.** *Researcher* 2012;4(11):59-69]. (ISSN: 1553-9865). http://www.sciencepub.net/research. 7

Keywords: solar dryer, passive. Integral, cassava, chips, intensity, efficiency, fungi, Perspex, moisture content and transmittance.

1. Introduction

The energy available in the world can be classified into renewable and non-renewable source. In many rural locations in Africa and most developing countries, grid-connected electricity of energy are either unavailable, unreliable or for some too expensive. Renewable resources are those, which are being replenished through natural processes within a relatively short time. Example of solar radiation is bio-fuel power, and water power. Non-renewable resources are depleted at a much a faster rate than their replenishment if any at all. Examples include fossil fuel energy and nuclear fuel energy [1-8].

The energy resources commonly and abundantly used at the moment are non-renewable and are bound to be exhausted. The fossil fuel for example is non-renewable and it is estimated that 29 million tones fuel per year of carbon goes into the formation of fossil fuel. Nuclear fuel energy, which in the 1960's appear to be a source of hope is faced with safety problems, in addition, Uranium is exhaustible. The renewable bio fuels like water power and wind power are minimal in supply and limited to specific places, hence there is quantity and distribution problems. For example, hydro-electricity can only be generated where there is waterfall. Sunlight or primary solar radiation represents the only totally inexhaustible energy resource that can be utilized economically to supply man's energy at all times. It comes from that fusion reaction involving the formation of helium gas from hydrogen atoms. In this process, it is estimated that 4.7×10^6 tones of matter are converted to 3.8×10^6 of energy. It implies that from the estimated mass of the sun, it will take 4 million years for the sun to be adopted. Hence within a time frame of million years, solar energy will always be available [12]

Drying is a method of food preservation that works by removing water from the food, which prevents the growth of micro-organisms and decay. Drying food using sun and wind to prevent spoilage has been known since ancient times. Water is usually removed by evaporation (air drying, sun drying, smoking or wind drying) but in the case of freeze- drying, food is first frozen then water is removed by sublimation (3).

There are different methods for drying each with their own advantages for particular applications; these include Bed dryers, fluidized bed dryers, shelf dryers and sunlight [4].

Drying involves the dehydration of the material such that the moisture is extracted from the product by heating the passage of a mass around it to carry away the released vapour. The passage of air over most food takes away moisture until it becomes saturated until an absolute humidity is reached. But the capacity of air for taking up this moisture is dependent on its temperature. Because the larger the uptake of moisture the higher the temperature and also the absolute humidity. If air is warmed, the amount of moisture not remains the same but the relative humidity falls, and the air is therefore enabled to take up more moisture from its surrounding [14]..

The open drying method: this method has utilized over the years, and it involves keeping the material to be dried in the open space for heating by solar radiation and by differential heating, the air above the drying mass is drawn.

The basic principle of drying is that , at a particular temperature, grain will lose moisture to the surrounding air whenever the surrounding air has a relative humidity lower than the equilibrium for the given grain moisture content (6). The converse is also true, i.e. the cassava chips will take on moisture, if the air has a higher relative humidity. To dry cassava chips in store, the storage atmosphere, as it takes on moisture, needs to be replaced regularly with drier and ambient air. This sounds simple, but two issues need to be considered: the force required driving it through the cassava chips and the quantity of air required to remove the moisture. A typical 100tonne silo can have a cassava chips bed depth of 5M and require 2.5 million cubic meters of air to dry the grain. Where the ambient conditions are too humid, supplementary heating can be used to heat the air, thereby reducing relative humidity. This is different from using a conventional hot air dryer in the sense that we are using only enough heat to reduce the relative humidity to at or just below the equilibrium level [9]. The most heat that I have used in my work is to give around a 10°C temperature rise to the input air.

The drying strategy varies between applications. Many summer harvest crops can be dried on 24-hour, around the clock fan running regions, as the local climatic conditions are usually very dry. Other crops and regions require a more selective fan operation cycle to eliminate the higher humidity times (usually at night and early morning and on wet days) Still other strategies require supplementary heat which will give 24 hour run times. Experiences have shown that there is a number of factors to balance when promoting in- store drying system to farm conditions. They are: system cost; available power supply (not many farms have the ideal-three-phase power); sufficient air flow to avoid condensation on the top of the grain mass; small enough fan (to reduce cost and power requirements); and acceptable drying times [4].

The rate at which free moisture is removed from crops doesn't remain constant. The speed and efficiency of drying depends on the flow rates temperature and humidity of the drying air. Naturally, high flow rates and high temperature tends to induce a quicker drying rate since low temperature may not give sufficient drying force to drive the moisture within the crop, and low- flow rates will slow down the evaporation process from the surface of the crop.

The drying process for many materials is characterized by periods of different drying rate. In the case of non-hygroscopic materials, the materials in which drying can be carried to zero moisture content; the first period is one of the constant drying rates. During this period, the rate of evaporation from the surface of very materials per unit drying area is constant. The materials are usually fully saturated and have a surface covering of free water, which evaporates at a rate determined by the temperature and humidity of the air its rate circulation. The rate of moisture removal decreases the second period. It is known as the failing rate period, in this case, the case of drying decreases because the rates of moisture transfer within the material to the surface is less than the evaporation rate from the surface of the drying medium. The failing rate-drying period is characteristic of hygroscopic material. Take into the consideration the graph of the drying rate the residual moisture content. As can be seen, the non-hygroscopic material continues to decrease until moisture content is zero [10].

In this case the hygroscopic materials, it can be seen the constant and falling rate are similar to the non-hygroscopic to some extent. The failing rate is similar until the unbound moisture within the material is removed. Then, the material experienced further drops in the drying rate due to some of the bound water being removed until the moisture content to the material provides a vapour pressure now greater than of the drying air. The drying rate thus becomes zero due to the equilibrium between the vapour pressure of the air and that of the material being dried [11]. Concentrating solar collector make use of only direct rays from the sun, the diffused rays are lost. Because of this, they must continually).

2. Experimental methods

The integral passive solar dryer been designed consist of a water glass glazing material and granite stone absorbers. Plywood insulation is used rather than the conventional one which is metal.

The following were considered during the conceptualization of this design: desired dryer temperature, insulation since heat ought to be conserved within the dryer, absorber, optimum dryer temperature, and required the dryer capacity (30Kg), cost (Maintenance).

The dryer measures about 1840mm in length. This implies that the trays are about 900mm each. The dryer and tray dimension go a long way in determining the optimum weight of cassava chips that can be dried on it. The generous dryer height of about 430mm provides enough area for air inflow and outflow.

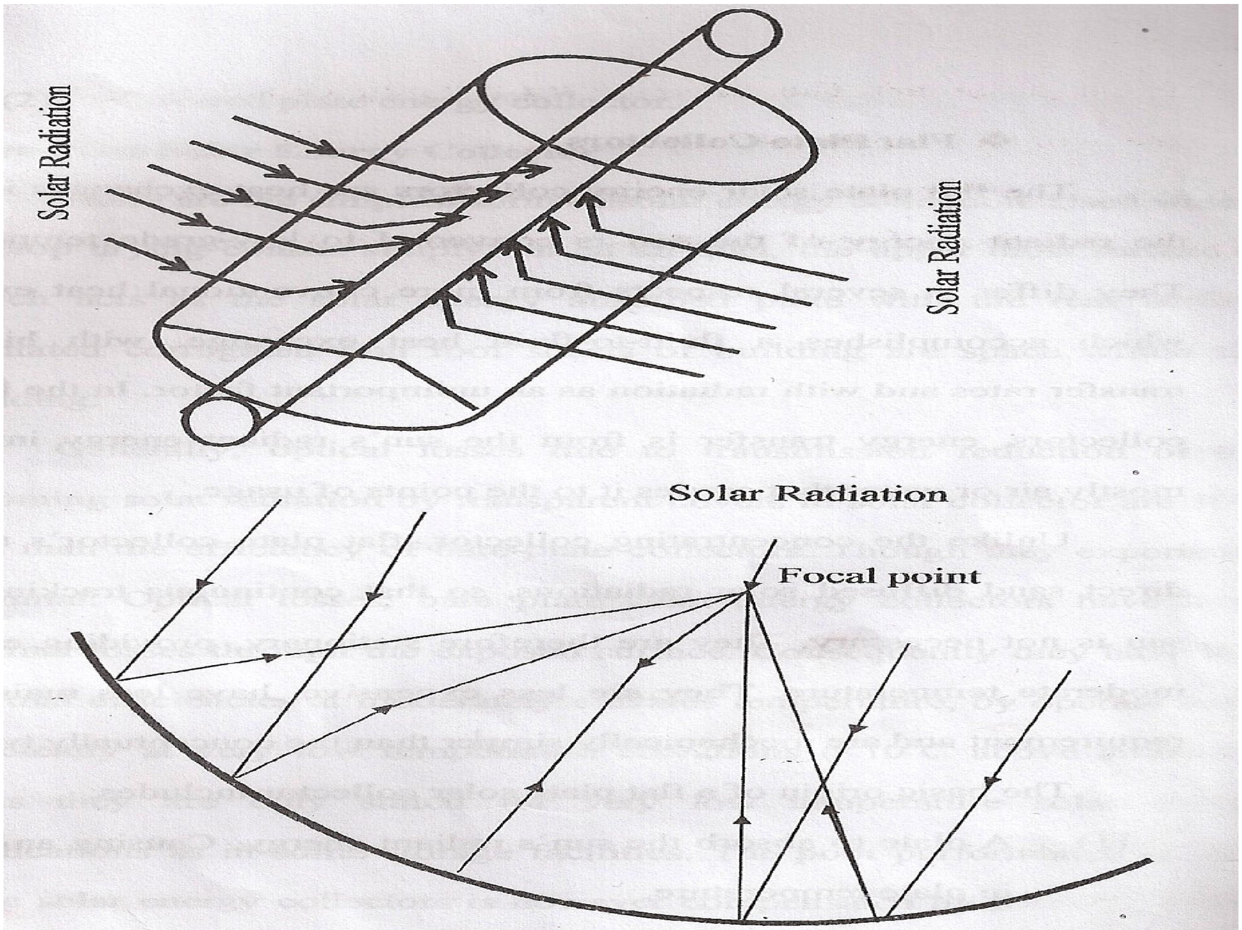


Fig.2.1: Concentrating (Focusing) collectors.

The width of the solar dryer is about 1250mm and has an inlet area sealed with a net which doubles to allow air inflow and reduces the effect of rainfall. The inlet area measures about (1250*150) mm^2. The drying rate is determined by the combined effect of the air inflow and the solar intensity.

The optimum temperature of the chamber is very important because the higher the temperature, the more the alterations the food quality while the lower the temperature, the slower the crops would get dry and hence more food spoilage. A balance has to be stroked between these two extremes [4].

The desired airflow rate is a function of the average wind speed and the inlet and outlet area. A poor inflow rate is observed with the simpler almost uniform level inlet and outlet. Increasing the vent area by opening vent covers will decrease the temperature and increase the airflow without having a great effect on the relative humidity of the entering air. In general more airflow is desire on the early stages of drying to remove free water or water around the cells and on the surface. Reducing the vent area by partially closing the vent covers will increase the temperature decrease the relative humidity of the entering air and airflow. This would be the preferred set up during the later stages of drying when the bound water needs to be driven out of the cells and to the surface. Since the dryer is supposed to conserve heat for drying of the crop and insulator is present within the dryer.

An absorber in this case, granite stones popularly call chippings was used for heat storage for subsequent heat energy release at night (or low solar radiation periods).

3. Material Selection:

The selection of materials used in the construction of the dryer is highly influenced by the market, climatic conditions of dryer location and cost.

Solar Dryer Cover: Water coloured transparent glass of 5mm thickness was used as glazing material. Glass was preferred to Perspex due to its higher strength and brittleness (non-susceptibility to breakages). The selected glass thickness of 5mm was to aid in heat conservation within the drying unit. Four sheets were purchased which were cut down to the required size. Glass has a transmissivity of about 0.9 which is satisfactory. The glass material was sealed with a flash band to reduce heat losses and hold the glass in place.

Chippings or gravel as they are called were painted black using paint and coal tar to make then perfect absorbers of heat. This choice was preferred to metal plates due to its relative cheapness:

4. Drying Chamber

The cover tilt angle was calculated using the local latitude. The optimum tilt angle for solar collectors for crop drying is the sum of the local latitude and the angle for the solar dryer. Hence, for Minna which lies on latitude 9°N, it implies that the solar tilt angle as stated above should be 24°. In the design of the solar dryer, several angles are thought of such as the volume of the dryer. This depends on the capacity of the dryer. In this case, the dryer has the capacity of 30kg though the tests were carried out for just 10kg, each tray contained 2.5kg and it was occupying barely ¾ of the tray. (James, 1983)

The design parameters are: quantity of cassava chips to be dried (W_1) = 10kg, initial Moisture content of wet cassava chips = 56.4%, desired final moisture content = 12-14% and mean daily global radiation of water from wet cassava = 11J/m^{2}.

Operation Equation:

$$\eta L A_c n = M_w H \quad (1)$$

$$Q_u = \eta L A_c n \quad (2)$$

Where

Q_u = Total amount of solar energy available to evaporate 3.42kg of moisture from 5kg of wet sliced cassava

η = Assumed overall efficiency of the dryer

L = Solar insulation of the area drying is taking place.

A_c = Surface area on which drying takes place.

n = number of days required for drying.

The total required to evaporate the same quantity from 10kg of wet sliced cassava surface is given as

$Q_w = M_w H$ (3)

M_w = Quantity of moisture to be removed from 5kg of wet sliced cassava chips.

Q_w = Total energy required to evaporate 5.63kg of moisture from 10kg of wet sliced cassava chips

H = Latent heat of vaporization moisture from surface of slices wet cassava ships.

5. Chimney Design

The chimney was designed and fabricated to be detachable so as to create an avenue to get into the solar if desired. It is also circular with as little edges as possible to reduce drag on the exhaust gas. It incorporated a rain cap so that while keeping out the rain does not contain the hollow that captures the exhaust gas and allows it to transform back into the liquid phase. (Morris, 1981)

The chimney was made with a flanged joint and joined to the solar dryer by means of 10mm steel bolts. A rectangular transition section was then constructed to take the exhaust gas from a rectangular area of 0.250 m^2 to a circular area of 0.0314m^2. A length of circular pipe was then attached to the elbow. On the top of the pipe, was a rain cap made up of two inverted cones. The top one was to keep out the rain while second one was to provide a streamlined end for the exhaust gas to exist the chimney. All the parts were to be made out of 1.2mm mild steal sheet because it is light enough not to cause undue stress on the flange joint and strong enough to withstand distortion under normal use.

To get the specifications for the chimney and assumed diameter of 100mm was chosen and the following equations were applied.

$$H_{min} = \frac{(E-(-E^2-4DG)^{0.5}}{2D}$$

$$H_{opt} = \frac{(E+(-E^2-4DG)^{0.5}}{4D} \quad (4)$$

Where:

E =

$$2g(\frac{VT}{T_1}+\frac{V_P}{P}+1779.25\frac{(VK_f)^{0.25}P_2)}{d^{1.25}}V_w{}^2K_w$$

$$D = 2g(\frac{(VT)}{T_1}+\frac{V_P}{P}+1770.25\frac{(VK_f)^{0.25}}{d^{1.25}}P_2) \quad (5)$$

6. Design Calculations

The Inclination angle of the solar collector is gotten from the addition of the local latitude of 9º to a constant of 15º.(Minna on latitude 9°N). Thus inclination angle is (15+9) º = 24º (James, 1983), height of 285mm was obtained for the inclination angle.

$$\eta L A_c n = M_w H \quad (6)$$

The quantity of heat required to dry cassava chips of 30kg

Q = C_w x × x ΔT (7)

where C_w = Specific heat of water

× = amount of water to be removed

Temperature difference (ΔT) = (T_{dryer} - T_{amb}) + (latent heat of vaporization x ×), is the amount of heat needed to remove × quantity of water at T_{dryer}

The direct solar dryer is therefore required to dry 14.42kg of water. Typically a drying rate of 0.25kg/hr would be expected for a solar dryer depending on the design and climate. Time required for 14.42kg of moisture content in 30kg cassava chips

$$\frac{14.42}{0.25} = 57.68hours \approx 58hours$$

Effective sunshine hour is always in the hour of 1000hrs to 1700hrs, for variation and safety, if the weather is favourable. Number of days required to dry 30kg of cassava chips = 58/7 = 8days

The heat required in drying 30kg of cassava chips:

$$Q = (M_w x C_{pw} x(T_o - T_1)) + (L_{vx} x M_w)$$

$$= (30x1.49x(45-29) + (2501x14.42)$$

$$256 + 36,064.42$$

$$= 36,320.42KJ$$

The mass of air required,

$$M_a = \frac{Q}{C_{pa}(T_a - T_1)} \quad (8)$$

$$M_a = \frac{36,320.42}{1.005(45-29)}$$

$$M_a = 2,258.73kg$$

The mass flow rate of air over 76hours, converting to kg/sec

$$M_a = \frac{2,258.73}{76x3600}$$

$$M_a = 8.256x10^{-3} kg/\sec$$

$$Q = M_a x C_{pa} x(T_0 - T_1)$$

$$Q = 8.256x10^{-3} x1.005x(45-29)$$

$$Q = 0.1327565KJ/\sec(orKW)$$

The area of collector that will produce the required heat above is given by the following equation.

$$A_c = \frac{M_a C_{pa}(T_o - T_{i)}}{F_R(\tau\alpha)G} \quad (9)$$

$F_R(\tau\alpha) = 0.8$, using the generic values provided for glazed collectors but when thermo-physical properties values are selected we have: $F_R = 0.9$, $\tau = 0.84$ and $F_R(\tau\alpha) = 0.6804$

$$A_c = \frac{0.1327565}{0.68x300}$$

$$A_c = 6.508x10^{-4} m^2$$

The velocity at which winds leave the exhaust is obtained as follows

$$U_T = \frac{2\pi H^{T^{0.5}}}{T_1} = \frac{2x\pi x1.2^{16^{0.5}}}{303} = 0.043m/s$$

$$U_A = \frac{(2\pi H^T)^{0.5}}{P_1} = \frac{(2x\pi x1.2^1)^{0.5}}{1} = 2.746m/s$$

$$U_p = V_w (K_w)^{0.5}$$

$$= 0.3x - (0.225)^{0.5} = -0.142m/s$$

$$U_t = U_T^2 + U_A^2 + U_P^2$$

$$= (0.043)^2 + (2.746)^2 + (-0.142)^2 = 7.52m/s$$

The efficiency (ŋ) of a machine is defined as:

$$ŋ = \frac{useful..workdone}{work..input} x100 \quad (10)$$

Thus Cassava chips of 2.5Kg were dried to 1.2Kg by the machine.

$$\eta = \frac{1.3}{2.5} x100 = 52\%$$

The efficiency of the machine is 52%.

Thus the efficiency of the open air drying when 1.5kg of cassava chips were dried to 0.8kg is

$$ŋ = \frac{useful..workdone}{work..input} x100 \quad (11)$$

$$\eta = \frac{0.7}{1.5} x100 = 48\%$$

7. Experimental results and discussion

The following devices were used in testing the drying for the drying rate temperature variations: thermometer: it's a temperature device and was used to check the temperatures of ambient, tray 1 to 4 and the temperature at the chimney exit. Thermometers' with reading accuracies of 2 degree and 1 degree were employed, thermostat: It is also a temperature-monitoring device used also to check the temperature at the chimney exit. The thermostat used was a digital thermostat and it makes use of thermocouples in temperature measurement. The thermostat could measure to two (2) places of decimal, weight Scale: This was used to obtain the drop in the mass of the chips in each tray. The reading accuracy of the weighing scale used was 2.5kg. Hence the values of masses obtained were of high precision, solar Insolation values were obtained from the PV unit of the energy Research Centre. The average wind speed was obtained as 0.3m/s from the same location, and values of relative Humidity: this could not be measured for the reason of unavailability of the device at that time.

8. Moisture Content Determination

A sample of the cassava was: first weighed using the laboratory digital scale. The initial mass of the sample was obtained as 42.38grams (weight basis), the same was then mashed to extract some of its moisture, the sample was then dried further in an oven until no mass loss was observed, when there was no more mass reduction, the product was brought out and reweighed. The dry weight was obtained as 18.495grams (Dry basis)

Moisture content is determined by the following equation:

$$\frac{Mass\,(Initial\,) - Mass\,(Final\,)}{Mass\,(Initial\,)} X100\,\%$$

The moisture content was obtained as

$$\frac{42.38 - 18.495}{42.38} x100\,\%$$

This implies that the dry matter content is (100-56.3) % = 43.7%

The moisture content of the final dried mass was obtained the same way. i.e laboratory tests to ensure the non-interference of dust and other particles which add to the mass and hence would affect computational analysis of the final moisture content. (Ajisegiri, 2001).

Performance tests on the dryer spanned a period of 4 week days though the drying was carried out in 76 working hours(I.e. from 1300hrs on the first day to 1700hrs on the four day) after which the cassava chips reached a moisture content of 12%. The thermocouple was used to determine the temperature on the first day while the thermometer was utilized on the subsequent days. The tests were carried out in two (2) phases: The loaded test was carried out for four (4) days, i.e. day 1 to day 4, the temperature readings were taken hourly starting from 1000hrs to 1700hrs for inlet trays, outlet trays, chimney outlet and ambient temperatures. The temperature of the inlet, outlet trays were designated as T_1 and T_2 respectively and were then tabulated, the dryer was then loaded with 10kg of cassava chips which was split into 2.5kg in each tray. (2.5kg for each tray), (iii) hourly temperature readings were taken for the inlet trays (T_1), outlet trays (T_2), chimney temperature (T_3) and ambient temperature from 1000hrs to 1700hrs, and the cassava chips in each inlets tray, i.e. tray 1 and 2 and the outlet trays i.e 3 and 4 were all weighed once a day and they were found to have the same mass.

Hence, only tray 2 and 4 were weighed hourly, the masses were about the same indicating uniform drying of cassava chips in the chamber.

9. Test Results.

The following tables show the test results for each day: day 1, day 2, day 3 and day 4 for the loaded test and their graphical representation respectively.

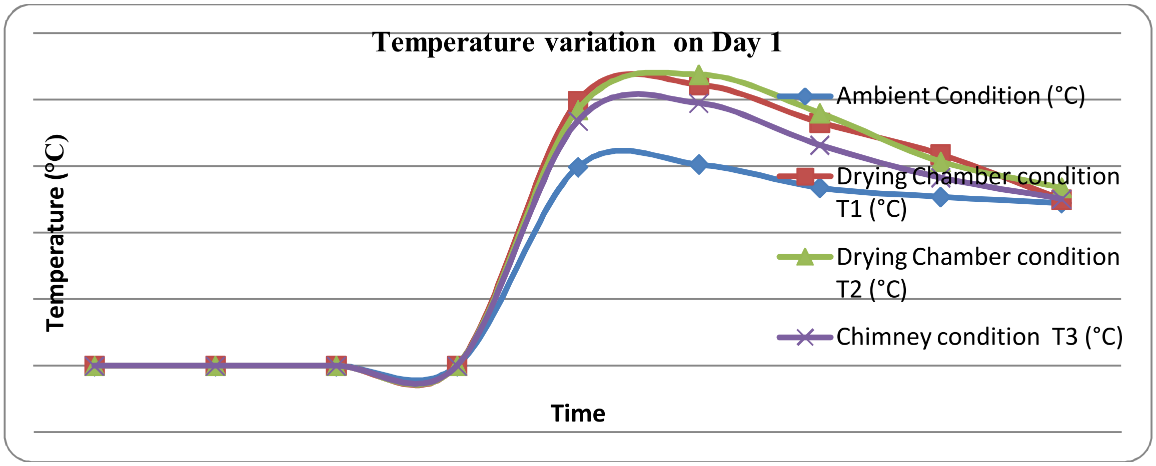
The temperature readings were taken hourly starting from 1000hrs to 1700hrs from inlet trays, outlet trays, chimney and ambient temperatures. The temperature of the inlet, outlet trays were designed as T_1 and T_2 respectively and were then tabulated.

Table1: shown weather Time

	Ambient Condition (°C)	**Drying Chamber condition**		**Chimney condition**	**Solar Insolation**	**Mass of chips (kg)**		
		T_1 (°C)	T_2 (°C)	**T_3 (°C)**	**(W/m²)**	M_1	M_2	M_3
1000hrs					179.4			
1100hrs					247.5			
1200hrs					459.4			
1300hrs	29.9	39.8	38.5	36.8	393.2	2.5	2.5	1.5
1400hrs	30.3	42.3	43.8	39.5	595.8	2.5	2.5	1.5
1500hrs	26.8	36.6	38.0	33.2	520.7	2.2	2.2	1.4
1600hrs	25.4	31.8	30.7	28.3	262.6	2.2	2.2	1.4
1700hrs	24.5	25.0	26.8	25.1	188.2	2.2	2.2	1.3

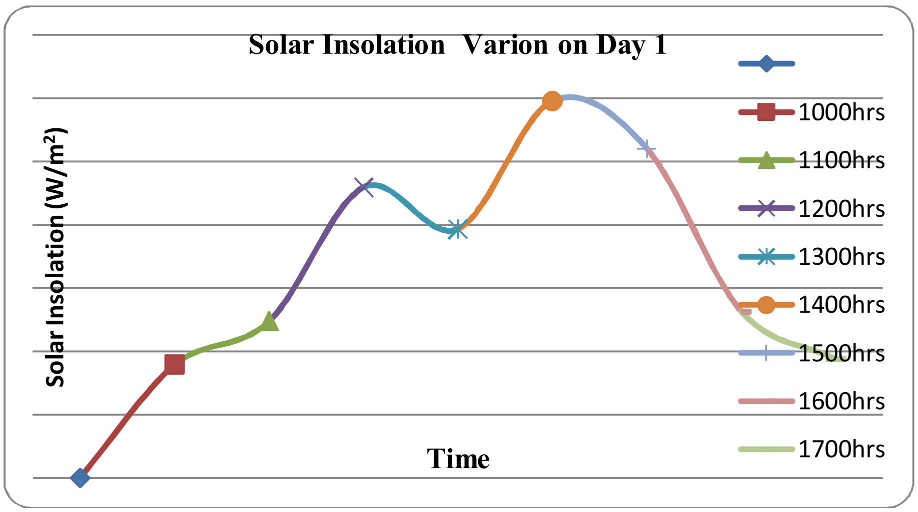
Drying Chamber, Chimney Condition and Mass reduction for day 1

Where T_1 (°C) = Temperature reading of the inlet trays (tray 1 and tray 2)
T_2 (°C) = temperature readings of the outlet trays (tray 3 and tray 4)
M_1 (kg) = Mass of inlet tray chips
M_2 (kg) = Mass of outlet tray chips
M_3 (Kg) = Mass of control tray chips



Graph1: Temperature variation on day

Observation: it was observed that the solar intensity rises at the hour of 1400hr and decreased at 1700hr



Graph 2: shown solar Insolation variation on day 1

The maximun insolation got to 595.8W/m^2 at the 1400hr which shows the effectiveness of dryer.

Table 2: Weather Drying Chamber, Chimney Condition and Mass reduction for day 1

Time	**Ambient Condition (°C)**	**Drying Chamber condition**		**Chimney condition**	**Solar Insolation**	**Mass of chips (kg)**		
		T_1 (°C)	T_2 (°C)	**T_3 (°C)**	**(W/m^2)**	M_1	M_2	M_3
1000hrs	21.8	23.0	23.5	23.0	313.6	2.0	2.0	1.2
1100hrs	22.3	24.8	25.6	24.8	298.3	2.0	2.0	1.2
1200hrs	23.5	24.5	25.5	24.5	378.6	2.0	2.0	1.2
1300hrs	24.0	27.0	28.0	28.0	532.2	1.9	1.9	1.1
1400hrs	24.0	28.0	31.0	29.0	473.5	1.9	1.9	1.1
1500hrs	28.0	32.0	33.0	31.0	393.9	1.8	1.8	1.1
1600hrs	26.0	27.9	30.8	29.0	320.1	1.8	1.8	1.1
1700hrs	24.0	26.0	27.0	26.0	223.5	1.7	1.8	1.1

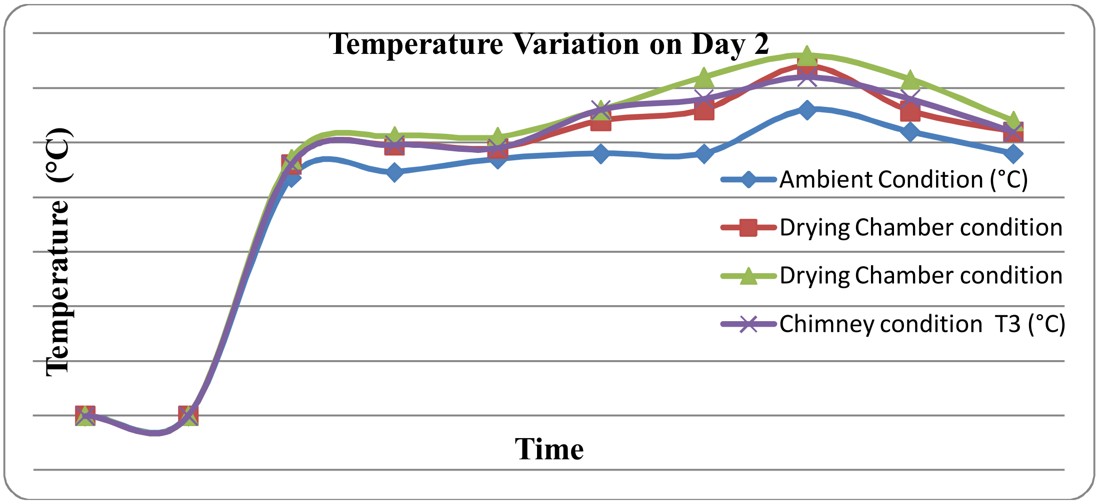
Where T_1 (°C) = Temperature reading of the inlet trays (tray 1 and tray 2)

T_2 (°C) = temperature readings of the outlet trays (tray 3 and tray 4)

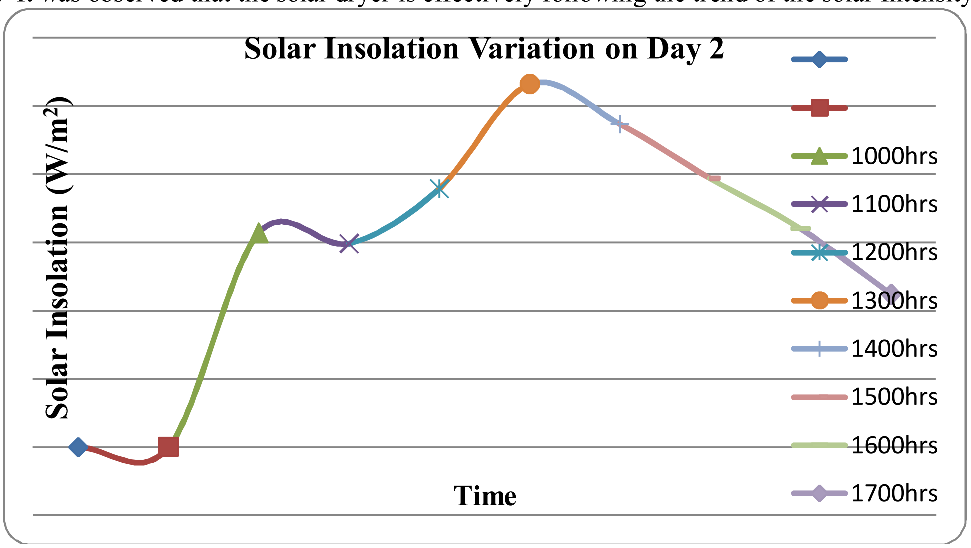
M_1 (kg) = Mass of inlet tray chips

M_2 (kg) = Mass of outlet tray chips

M_3 (Kg) = Mass of control tray chips



Graph 2: It was observed that the solar dryer is effectively following the trend of the solar Intensity.



Graph 3: Insolation Variation on day 2, It was observed that there is a sudden drag in the insolation level and a slopy collapse by the day.

Time	Ambient Condition (°C)	Drying Chamber condition		Chimney condition T_3 (°C)	Solar Insolation (W/m^2)	Mass of chips (kg)		
		T_1 (°C)	T_2 (°C)			M_1	M_2	M_3
1000hrs	25.5	27.0	29.0	27.5	471.5	1.9	1.9	1.2
1100hrs	27.0	30.0	31.5	31.5	470.5	1.8	1.8	1.2
1200hrs	26.5	28.5	31.5	31.0	433.6	1.7	1.8	1.2
1300hrs	24.0	27.0	30.0	30.0	686.2	1.6	1.7	1.1
1400hrs	27.0	35.0	34.0	32.0	502.8	1.6	1.6	1.1
1500hrs	29.0	34.0	37.0	32.0	756.0	1.6	1.6	1.1
1600hrs	27.0	31.0	33.0	31.0	589.0	1.5	1.5	1.0
1700hrs	27.0	32.0	35.0	31.0	195.6	1.5	1.5	1.0

Table 4: Weather Drying Chamber, Chimney Condition and Mass reduction for day 1

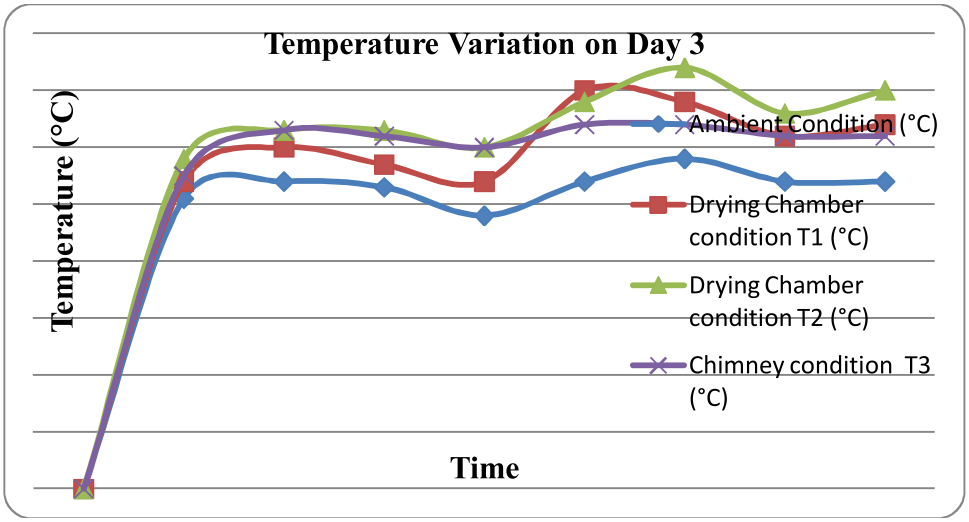
Where T_1 (°C) = Temperature reading of the inlet trays (tray 1 and tray 2)

T_2 (°C) = temperature readings of the outlet trays (tray 3 and tray 4)

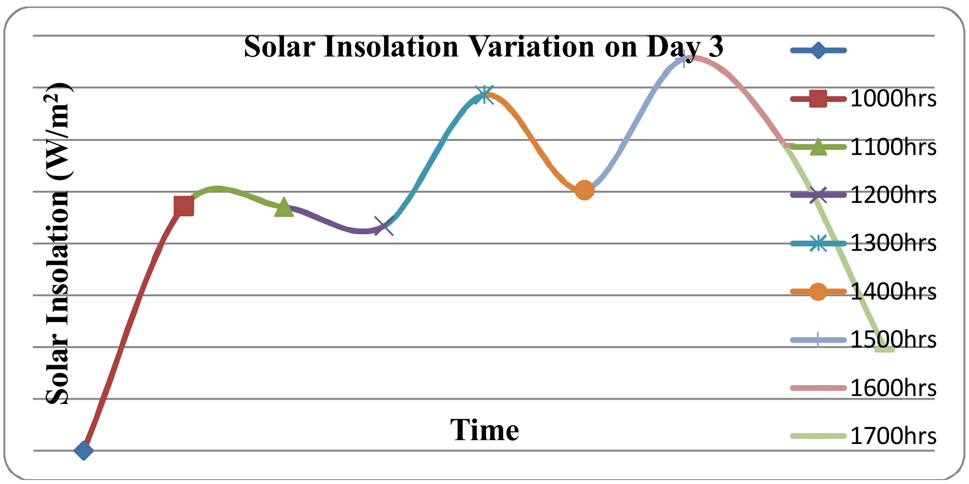
M_1 (kg) = Mass of inlet tray chips

M_2 (kg) = Mass of outlet tray chips

M_3 (Kg) = Mass of control tray chips



Graph 4: Temperature Variation on day 3, it was observed that the chimney absorbed more heat keeping relative to ambient temp.

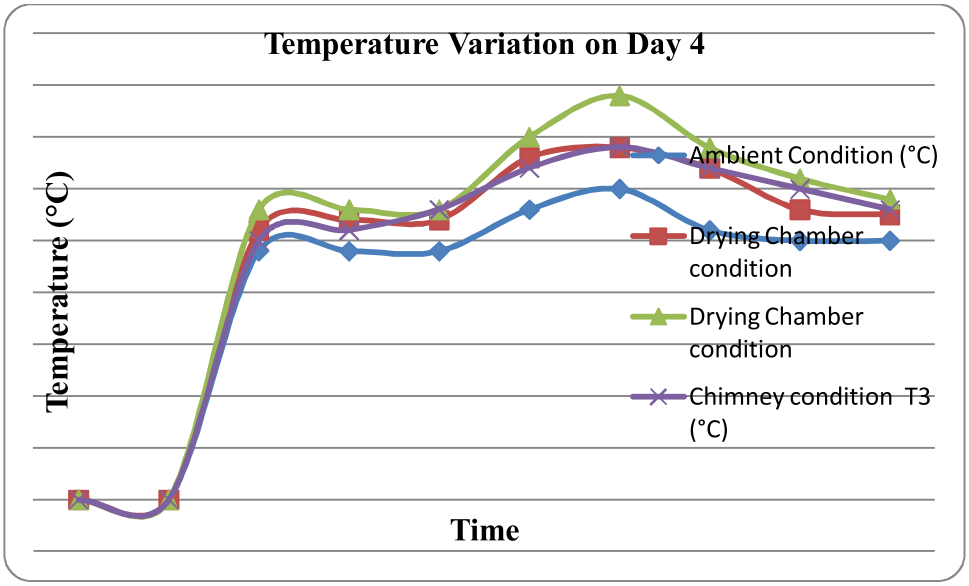


Graph 5: Solar Insolation Variation on day, it was observed that there was a drag in the early hour while a certain level was achieved and sudden late hour slopy collapse.

Table 5: weather Drying Chamber, Chimney Condition and Mass reduction for day 4

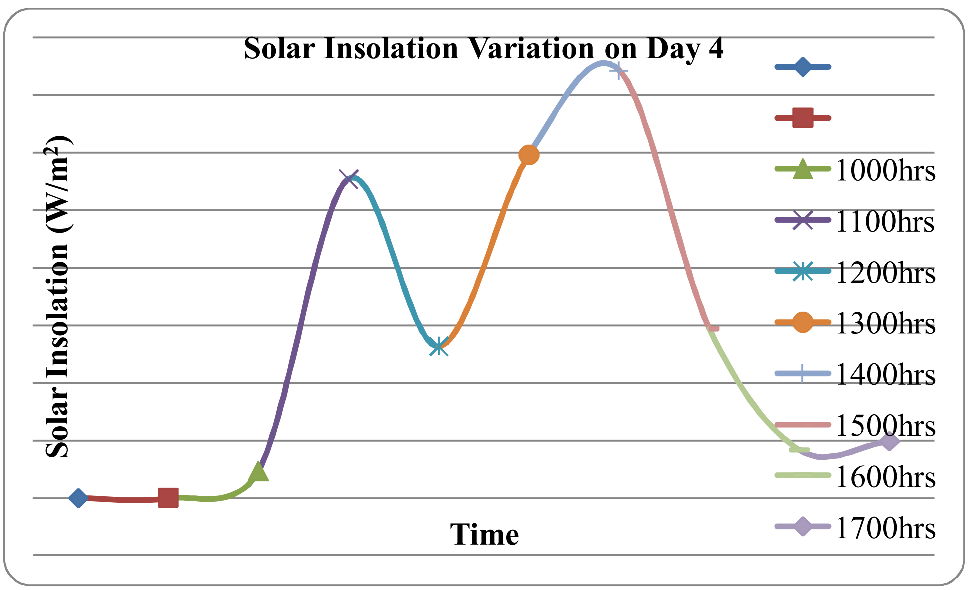
Time	Ambient Condition (°C)	Drying Chamber condition		Chimney condition T_3 (°C)	Solar Insolation (W/m^2)	Mass of chips (kg)		
		T_1 (°C)	T_2 (°C)			M_1	M_2	M_3
1000hrs	24.0	26.0	28.0	25.0	46.2	1.4	1.4	0.9
1100hrs	24.0	27.0	28.0	26.0	554.1	1.4	1.4	0.9
1200hrs	24.0	27.0	28.0	28.0	263.4	1.4	1.4	0.9
1300hrs	28.0	33.0	35.0	32.0	596.5	1.4	1.4	0.9
1400hrs	30.0	34.0	39.0	34.0	743	1.3	1.3	0.9
1500hrs	26,0	32.0	34.0	32	294.8	1.3	1.3	0.9
1600hrs	25.0	28.0	31.0	30.0	83.7	1.2	1.2	0.8
1700hrs	25.0	27.5	29.0	28.0	98.9	1.2	1.2	0.8

Where T_1 (°C) = Temperature reading of the inlet trays (tray 1 and tray 2)
T_2 (°C) = temperature readings of the outlet trays (tray 3 and tray 4)
M_1 (kg) = Mass of inlet tray chips
M_2 (kg) = Mass of outlet tray chips
M_3 (Kg) = Mass of control tray chips



Graph 5: Temperature Variation on day 4

Observation: It was observed that the peak of solar intensity for the day is attained at 1400hr.



Graph 6: Solar Insolation Variation on day 4

It was observed that in the early hour there was a sharp rise in the solar insolation which got to the peak and later descended at about 1400hr.

10. Test Analysis

The no-load test was carried out to obtain a general view of the variation of the performance parameters under varying atmospheric conditions and not to the optimum operating conditions of the dryer. The optimum operating conditions of the dryer cannot be ascertained from just a day's test and under very unfavourable conditions. Nevertheless, temperatures in the drying chamber got to about 45ºC though higher temperatures of about 55ºC where obtained though not at measuring times.

The performance tests were carried out and the solar dryer still reduced the moisture content to the required amount after 76hours of drying.

The chips in the solar dryer attained a moisture content of 9% after 76hours of drying while open air dried chips were dehydrated down to 18% moisture content under the same ambient conditions and same initial moisture content levels of 56.4%. This proves the important and need for solar dryers, the efficiency of solar dryers is retarded during the rainy sea, it's preferred to open –air-drying as shown in the graphs above. Under normal weather conditions (i.e. sunshine averaging at 7hours a day), the open drying method is normally slower than the solar than when the solar dryer is used. Other advantages of solar dryer over the traditional open drying method are: crop contamination, infestation by pests and spoilage of crops are reduces or almost eliminated with the solar dryers, solar dryer reduces the dust that clings to the particles, during the rainy periods, the solar dryers are preferred because of the covering (usually Perspex or glass), the solar collectors (in the case of this dryer, granite stones painted black) are very useful at night since they released the heat energy they stored during the sunshine hours, and the open air drying is more labour intensive since it requires monitoring during rainy seasons.

Conclusion

The efficiency of solar dryers is retarded during the rainy season. It's preferred to open air-drying as shown in the graphs. Under normal weather conditions (i.e. sunshine averaging at 7 hours a day), the open drying method is normally slower than when the solar dryer is used. Other advantages of solar dryers over the traditional open drying method are:

Crop contamination, infestation by pests and spoilage of crops are reduced or almost eliminated with solar dryer, the solar collectors (in the case of this dryer, granite stones painted black) are very useful at night since they release the heat energy they stored during the sunshine hours, solar dryer reduces the dust that clings to the particles and during rainy season, the solar dryers are preferred because of the covering (usually Perspex or glass) The recovery rate of chips from the roots is about 20% - 40% depending on initial dry matter content of the cassava roots and the final moisture of the chips. The factors that affect cassava drying time are the geometry (shape and size) of the cassava chips, the chip loading per unit drying area, air speed, temperature, humidity, radiation as well as dry matter of the fresh chip.

Future work

Modifications is still required, that more trays can be added to the dryer to increase the capacity of the dryer, the chip sizes could also be reduced for further better result, the incorporation of an air driven fan to the chimney will increase the flow rate in the dryer and addition of measuring devices will give room for easier measurement.

9/23/2012

Reference

1. Arinze, E.A., (1986) "Solar Energy for Crop Drying in Developing Countries: Solar Drying in Africa", A proceeding of a workshop held in Dakar, Senegal, pp 129-133.
2. Ajisegiri,E.S., (2001) "Solar Energy Application in Agricultural & Food Preservation",*Moisture content of food crops*, Minna.
3. Best, R. (1978) "Cassava Processing for animal feed", *Cassava harvesting and processing*, ed by Ghoninard, A., Cook, J.H., and Weber E.J., pp12-20, Lagos :Macmillian.
4. Boiln, H.R. , and Salunkhe, D.K. (1982)"Food Dehydration by Solar Energy ",*Critical Reviews in Food Science and Nutrition*, pp:327-354.
5. Duffie, J.A and Beckman, W.A., (1991) "Solar Engineering of Thermal processes" 2nd ed by Wiley Inter Science, New York, pp: 9-11.
6. Ekechukwu, O. C., (1997*), Review of Solar Energy Drying systems ii- An overview of Solar Dryer Technology*, Enugu, Udo and Sons.
7. Folaranmi, J., (2010), "Heat and MassTransfer"Mechanical engineering Department, Federal University of Technology. Minna
8. Iloeje. O.C., (2006) "Sources of Energy "Mechanical Engineering Department, University of Nigeria. Nssuka.
9. Iwena, O.A., (2010), *Essential Geography for Senior Secondary Schools*, Ibafo: tonad publishers.
10. James, D.R., (1983), Source Book for Farm Alternatives, New York: Mcgraw Hill.
11. Marco, P., (1996), "Cassava Crop History in West African ", *The Global Development strategy for cassava,* Academic press New York.
12. Manurung, F., (1994) "Technology of cassava chips and pellets processing in Indonesia, Malaysia and Thailand", *Cassava processing and storage* ed by Argullo, E. V., Nestel, B. and Campbell, M., New York: Mcgraw Hill.
13. Morris, S. (2011) "Retrofitting with National Convention Collectors", *Home Remedies-A Guidebook for Residential Retrofit,* Wilson, T.pp152-161, New York: Mcgraw.
14. Okegbile, J., (2012) "Solar Energy Studies", School of Engineering and Engineering Technology, Federal University of Technology, Minna.