DESIGN AND CONSTRUCTION OF A NATURAL CONVECTION SOLAR DRYER FOR DRYING TUBER CROPS IN MINNA, NIGER STATE, NIGERIA

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Absract
This paper presents the design and construction of a natural convection solar dryer for tuber crops. The dryer is composed of air heater (collector), drying chamber and air vent (inlet and outlet). A single glass cover tilted at an angle 19.4^o was used to cover the top of the dryer. The total area of the collector is 6.8m^2 and the air vent dimensions are 0.05m by 0.05m. The interior of the dryer was painted black while the exterior was gray. The heat loss through the insulation sides and the top cover is 2,223.60W. The efficiency of the constructed solar dryer is expected to be 45.82%. The design was based on the geographical location of Minna (Latitude and Longitude values: 9.37^{o}N and 6.30^{o}E) central part of Nigeria, and local meteorological data were obtained for proper design specifications. Locally available materials were used for the construction.

Keywords: Solar drying, Agriculture produce, Temperature

Introduction
Drying is an excellent way to preserve food and solar food dryers involves appropriate food preservation technology for sustainable development (Scalin, 1997). Drying was probably the first ever food preserving method used by man, even before cooking. It involves the removal of moisture from agricultural produce to provide a product that can be safely stored for longer periods of time (Oguntola *et al.,* 2012). Open-air and uncontrolled sun drying is still the most common method used to preserve and process agricultural products in most tropical and subtropical countries. However, being unprotected from rain, wind-borne dirt and dust, infestation by insects, rodents and other animals, the products may be seriously degraded to the extent that sometimes they lose market value, become inedible and the resulting loss of food quality in the dried products may have adverse economic effects on domestic and international markets. Some of the problems associated with open-air sun drying can be solved with a solar dryer, which comprises of collector, a drying chamber and sometimes a chimney (Modhlopa *et al.,* 2002). The conditions in tropical countries make the use of solar energy for drying food practically attractive and environmentally friendly. Dryers have been developed and used to dry agricultural products in order to improve market value and shelf life (Esper *et al.,* 1996). Most of these either use an expensive source of energy such as electricity (El-Shiatry *et al.,* 1991) or a combination of solar energy and some other form of energy (Sesay & Stenning, 1997). The small farmers have not adopted most projects of this nature because, either the final design and data collection procedures are

frequently inappropriate or the cost has remained unaffordable, and the subsequent transfer of the technology from researchers to the end user has been anything but ineffective (Berinyuy, 2004).

Adelaja *et al*. (2010) designed, constructed and tested a forced convectional solar dryer for the purpose of drying yam in order to study the moisture removal pattern. The researchers reported that the collector and dryer efficiencies were 65.6 % and 54.7 % respectively, while a moisture content removal of 75% and average drying rate of 0.0481kg/hr were recorded during solar drying of yam. The researchers observed that the yam dried in solar dryer appears better dried when compared with open sun-drying.

Bolaji (2008) designed, fabricated and tested a cabinet solar dryer in order to evaluate moisture flux in Yam chips and shelled corn. The results obtained indicate prospect for higher rate of moisture removal in solar dryer than open-air sun drying. The results also show that at lower liquid concentration in the food items, the moisture flux increases with increase in the liquid concentration and are constant at higher liquid concentration. The researcher reported that the rate of moisture removal from the food item is a function of both the temperature inside the dryer and intensity of heat.

Solar dryer requires solar energy for its operation, which is readily available in the Northern parts of Nigeria, and is a clean form of energy. It protects the environment and saves cost and time spent on open sun-drying methods, which dries food-items more slowly. The food items are also better protected in the solar dryer than in the open sun-drying methods, thus minimizing pest and insect attack and other forms of contamination.

In this study, the constructed solar dryer was use to conducted experiment and this was aim to determine the characteristics of the solar dryer system with regard to variations in external conditions (i.e. insolation and ambient temperature).

Physics of Solar Drying

(a) Heat by radiation obtained (from the sun), which is transmitted (through a glass cover), convected through air to the surface of the product and conducted to the interior of the product to:

(i) Increase its inner temperature.

(ii) Cause the formation of water vapour at its surface (product)

(b) Air from the surrounding absorbs warm moisture content from the surface of the product and evaporates.

These process keeps repeating until the product is completely dehydrated (Dried).

Drying can be expedite by:

(i) Increasing flow rate of drying air

(ii) Increasing temperature of drying air

(iii) Initial drying is restricted to the surface of the product and later on drying depends on the type of materials. These materials are grouped into two types:

(a) Hygroscopic: In these materials, drying is not possible up to zero moisture contents. Examples, grains, fruit and generally foodstuff. They have residual moisture that is not dried during drying process.

(b) Non-hygroscopic: In these materials, drying is possible up to zero moisture contents. Examples of these materials are grass and generally non-foodstuff.

In drying any materials through the solar dryer, the rules to keep in mind are:

(i) Sunlight through glass heats an enclosed space significantly. Need to control interior temperature.

(ii) Sunlight will heat a black surface much better than a white surface. Black absorbs more heat.

(iii) Warm air rises while cool air tends to sink therefore, convection chambers for dehydrators should make use of this fact to carry moisture away from the drying food.

Materials and Method

Materials: The materials used for the construction of the integrated solar dryer (See Plate I) include:

(a) *Plywood:* Plywood was used for housing the entire solar dryer and was selected being a good insulator and relatively cheap.

(b) *Glass:* Glass was used to cover both the collectors and the dehydrating chamber. Glass transmits the solar radiation into the drying system and resists the flow of heat energy out of the drying system.

(c) *Collector or air heater:* Two separate aluminium sheets of dimensions 0.55cm thickness, 34cm length and 20cm width inclined at angle 19.4° to the horizontal surface within the solar dryer were used as collector. This inclination is to enhance air circulation and intensity of the solar radiation in the dryer as established by Adegoke and Bolaji (2000); Artlet *et al*. (1999), and several other researchers.

(d) *Surface coating of the aluminium sheet:* Selective coating was used to coat one plate by painting (physical technique) and another by spraying (Chemical technique) with an ordinary black paint.

The aim of this is to determine the better absorber of heat between the two techniques since the techniques are the most two common methods of coating the collector surface.

(e) Wire net and wooden frames: These were used for constructing the tray where the yam slices to be dried are kept in the drying chamber.

(f) Insect net: This was used to cover both inlet and outlet vents to prevent insect from entering solar dryer system.

Method

Since the whole frame was made of plywood's and the top cover is glass, the constructed solar dryer was fixed together with nails and glue.

The solar dryer was constructed with locally available materials as highlighted above. As depicted in plate 1, the dryer was made of plywood, metal sheet and glass. The metal sheet used was aluminium of 0.55 cm thickness with dimensions 34 cm by 20 cm. The glass was cut into size of 60cm by 34 cm and was used to cover the top of the dryer. The tray was made with wooden frames and net cloth to allow free flow of air. The dimension of the tray (drying chamber) was 20cm by 20 cm.

The designed and constructed dryer is shown in Figure 1 with the dimensions while Plate I shows the dryer.

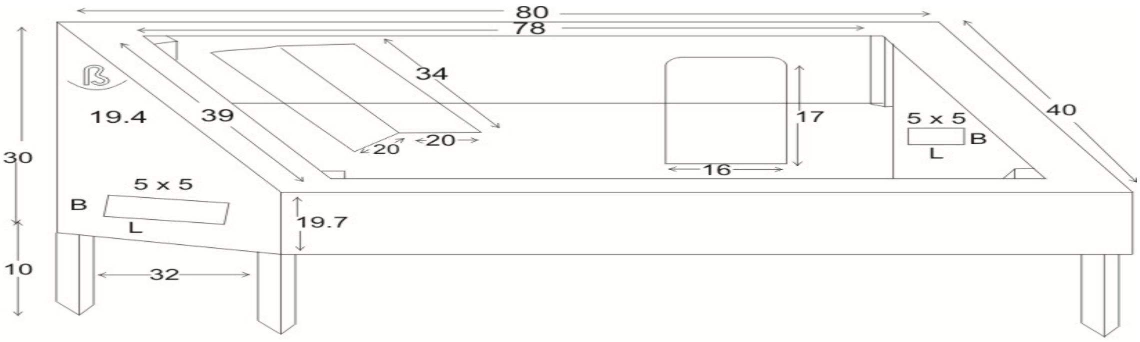

Figure 1: Schematic Diagram of Solar dryer (All Dimensions are in cm)

Plate I: The prototype integrated solar dryer

Design Features of the Dryer

As shown in Plate I, the interior of the solar dryer was painted black to enhance the absorption of heat energy while the exterior was painted gray to reduce the effects of weather and insect attack on the plywood (Oguntola *et al*., 2012). The front of the dryer as depicted in Plate I is higher than the rear, giving the top glass cover an inclination of about 19.4^0. This is approximately 10^0 more than the local geographical latitude of Minna. The two collectors within the dryer were also inclined at the same angle (i.e. 19.4^0). These inclinations are to allow easy run-off of water, enhance air circulation and most importantly to increase incident solar radiation on the collector as established by Artlet *et al.* (1999).

The dryer was also provided with air inlet and outlet holes at the sides. The outlet vent is at higher level situated on the side of drying chamber while the inlet vent is located on other side of the dryer above the collector. This is to ensure that there is movement of air through the vents due to a thermo-siphon effect, which creates an updraft of solar heated air laden with moisture out of the drying chamber. The source of airflow is natural convection.

Design Calculations

i. Angle of tilt (β) of the solar collector: The angle of tilt(β) is calculated as follows (Sukhatm, 1996):

$\beta = 10° + \text{lat}\phi$ (1)

Where ϕ is latitude of Minna where the solar collector was used to dry yam slices ($\phi = 9.37°$).

Therefore, tilt angle (β) was obtained as

$\beta = 10° + 9.37°$

$\beta = 19.4°$

ii. Insolation on the collector surface (I_c): The hourly average of daily insolation on collector surface was obtained from Davis weather instrument installed at Federal University of Technology by the Physics Department (See Appendix A) as:

$I_c = 425.11 W/m^2$ (2)

iii. Determination of collector area(A_c)- Area of collector was calculated using the relation (Oguntola *et al., 2012*):

$A_c = L_c \times B_c$ (3)

$A_c = 34 \times 20 = 0.068\ cm^2$

$A_c = 0.068\ m^2$

iv. Determination of air mass (M_a) and air volume (V_a)- The mass flow rate of air was determined as (Oguntola *et al., 2012*):

$M_a = V_a \times \rho_a$

Where

$\rho_a = 1.28 kg/m^2$ (air density)

V_a = average wind speed x air gap width x collector width

$V_a = 21.42 \times 0.05 \times 0.2$

$V_a = 0.2142 m^3/s$ (air volume)

Thus mass flow rate of air:

$M_a = 0.2142 \times 1.28$

$M_a = 2.74 \times 10^{-1} kg/s$

Oguntola *et al*. (2012) suggested that for hot climate passive solar dryers, a gap of 5 cm should be created as air inlet and outlet respectively.

Note: The hourly average daily wind speed at Federal University of Technology Bosso Campus Minna, was obtained as 21.42 m/s (See Appendix A)

v. Determination of heat loss from solar collector- The total energy transmitted and absorbed is given as (Oguntola *et al., 2012*):

$I_c A_c \tau\alpha = Q_u + Q_L + Q_S$ (5)

Where

$\tau\alpha$ = transmittance absorbance and is given as (Oguntola *et al.*, 2012):

$\tau\alpha$ = 0.9 x 0.86

Q_u = energy absorbed by air (W)

Q_L = energy loss by solar dryer (W)

Q_S = energy stored and is considered negligible

Therefore, equation 5 becomes

$I_c A_c \tau\alpha = Q_u + Q_L$

Which yields:

$$Q_L = I_c A_c \tau\alpha - Q_U \quad (6)$$

However, Q_u and Q_L are given as

$$Q_u = M_a C_p (T_o - T_i) \quad (7_a)$$

$$Q_L = U_L A_c (T_o – T_i) \quad (7_b)$$

Putting equation 7a and 7b into 6 gives:

$U_L A_c \Delta T = I_c A_c \tau\alpha - M_a C_p \Delta T$

Therefore, overall heat transfer coefficient of the absorber U_L was determined as:

$$U_L = \frac{I_c \; A_c \; \tau\alpha \; - M_a \; C_p \; \Delta T}{A_c \; \Delta T} \quad (8)$$

Where

I_c = Insolation on collector surface (425.11W/m^2)

A_c = Collector Area (6.8m^2)

$\tau\alpha$ = Transmittance absorbance (0.9 x 0.86 = 0.774)

M_a = Air mass (2.74 x 10^{-1}Kg/s)

T_0 = Maximum temperature required for dry food items (60^{o}C)

T_i = Minimum temperature required for dry food items (30^{o}C)

ΔT = Differences between T_o and T_i (30^{o}C)

Hence, putting the values of the above parameters into Equation 8 gives

$$U_L = \frac{425.11 \times 0.068 \times 0.7744 - 2.74 \times 10^{-1} \times 1.00695 \times 30}{0.068 \times 30}$$

$$U_L = \frac{22.386 - 8.277}{2.04} = \frac{14.109}{2.04} = 6.92$$

U_L = 6.92 W/m^2 ^{o}C

As established by Whitfield (2000), the minimum temperature for drying food is 30^{o}C and the maximum temperature is 60^{o}C while 45^{o}C and above is considered average and normal for drying vegetables, fruits, roots and tuber chips, crop seeds and some other crops.

Thus, heat loss through the insulation sides and the top cover glass was obtained using Equation (7_b) as

Q_L = 6.92 x 0.068 x 30

Q_L = 14.12W

Results and Discussion

Solar dryer was tested to determine how its performance would vary in respect to variations in external condition such as insolation, ambient temperature and wind speed respectively.

The experiment was conducted on 7th November, 2012. The drying chamber was empty but partially covered with duplicating paper to serve as heat absorber in the chamber.

In this experiment, the parameters of interest were: Temperature of solar dryer (sprayed collector, painted collector and drying chamber), ambient temperature, wind speed and the insolation. The experimental set-up for the test is shown in Plate II.

Plate II: Experimental Set-up

The slant top surface of the solar dryer was made to face south direction to ensure maximum incident solar radiation. Three thermocouples and a multi-meter were set in place to measure the temperature of the sprayed collector (T_{sc}), painted collector (T_{pc}), and drying chamber (T_{dc}) respectively. An hourly measurement of the temperature at a specific location was carried out between 8.00a.m and 4.00p.m local time. The corresponding hourly ambient temperature (T_{am}), insolation (IS), and wind speed (WS) were also measure and recorded by Davis Weather device (vantage pro-2) installed at F.U.T., Physics Department. The weather station was just few meters away from the site of the experiment.

The results of this experiment are shown in Table 1, 2, 3, 4 and Appendix A.

Table 1: Solar dryer without Yam (Preliminary Experiment, Day 1)

Time (hrs)	T_{sc} (^oC)	T_{pc} (^oC)	T_{dc} (^oC)	T_{am} (^oC)	IS(W/m^2)	WS
8.00	25.00	26.00	22.00	26.30	235.00	22.80
9.00	43.00	44.00	45.00	28.70	452.00	23.40
10.00	56.00	58.00	55.00	30.20	692.00	23.40
11.00	58.00	59.00	57.00	30.20	236.00	23.40
12.00	68.00	70.00	64.00	32.60	192.00	24.30
13.00	71.00	73.00	59.00	32.80	736.00	23.40
14.00	66.00	67.00	51.00	34.30	784.00	23.30
15.00	52.00	55.00	44.00	34.10	477.00	21.30
16.00	37.00	39.00	35.00	33.60	190.00	21.70
Total	476.00	491.00	432.00	282.80	3994.0	207.0
Average	52.89	54.56	48.00	31.42	443.78	23.00

Note: T_{sc} = Temperature of sprayed collector, T_{pc} = Temperature of painted collector, T_{dc} = Temperature of drying chamber, T_{am} = Ambient Temperature, IS = Insolation and WS = Wind speed

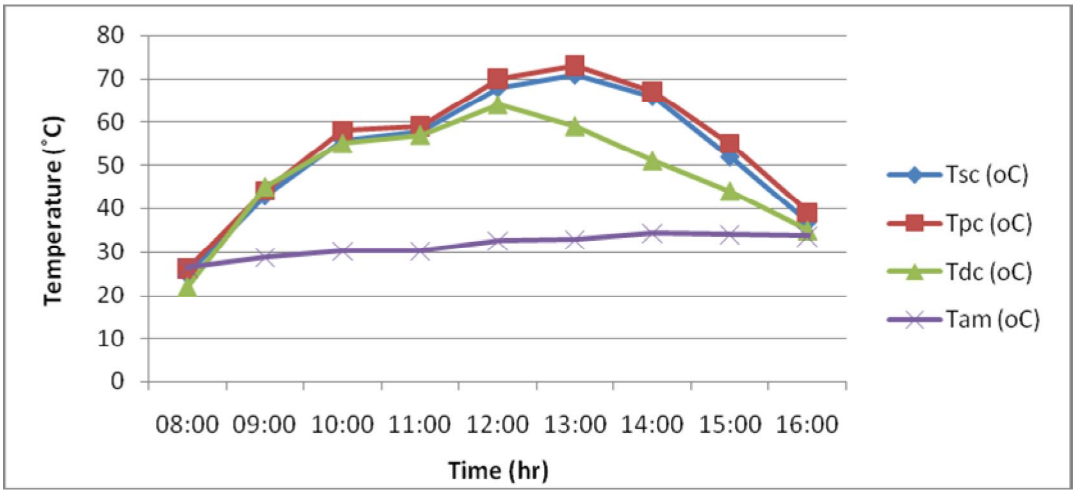

Figure 2a: Hourly variation of ambient (T_{am}), sprayed collector (T_{sc}), Painted collector (T_{pc}) and drying chamber (T_{dc}) temperatures on 07/11/2012

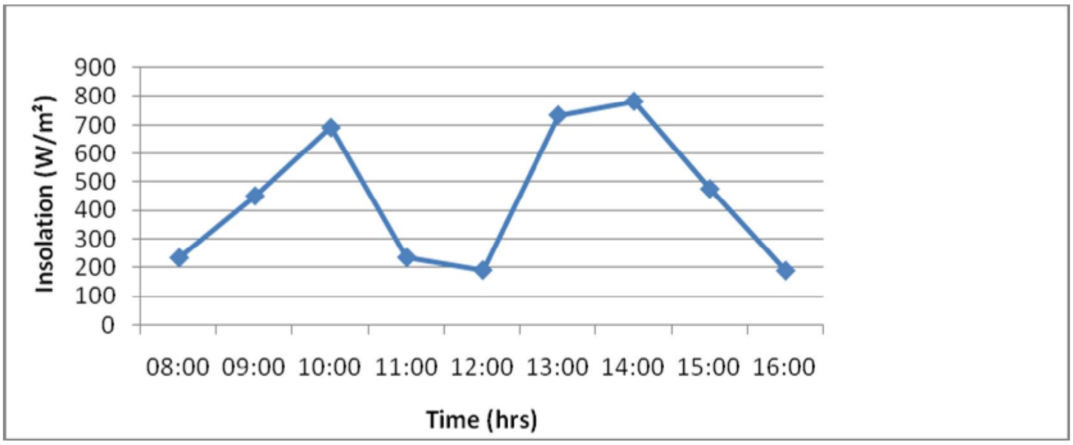

Figure 2b: Hourly variation of insolation on 07/11/2012 (See Appendix A)

Results

As can be seen from Figures 2a and 2b, the temperature of the different sections of the solar dryer [sprayed collector (T_{sc}), painted collector (T_{pc}) and drying chamber (T_{dc})] increased with increase in the solar radiation.

Figure 2a depicts that the heating temperature of painted collector (T_{pc}) was higher than the heating temperature of the sprayed collector (T_{sc}) and the temperature of drying chamber was greater than the ambient air temperature throughout the day.

It was also observe that high wind speed caused more heat loss from solar dryer and low humidity outside the dryer speeds-up the moisture removal from solar dryer.

Table 2: Solar dryer without Yam (Preliminary Experiment, Day 2)

Time (hr)	T_{sc} (°C)	T_{pc} (°C)	T_{dc} (°C)	T_{am} (°C)	Insol. (W/m^2)
8.00	29.0	30.0	25.0	26.3	110.0
9.00	39.0	40.0	36.0	27.2	264.0
10.00	43.0	44.0	35.0	28.8	335.0
11.00	48.0	49.0	44.0	29.3	336.0
12.00	50.0	57.0	47.0	30.9	291.0
13.00	70.0	71.0	58.0	31.3	649.0
14.00	63.0	64.0	43.0	32.3	616.0
15.00	42.0	50.0	39.0	33.6	591.0
16.00	40.0	43.0	36.0	32.8	280.0
Total	424	484	363	272.5	3472.0

Analysis Results

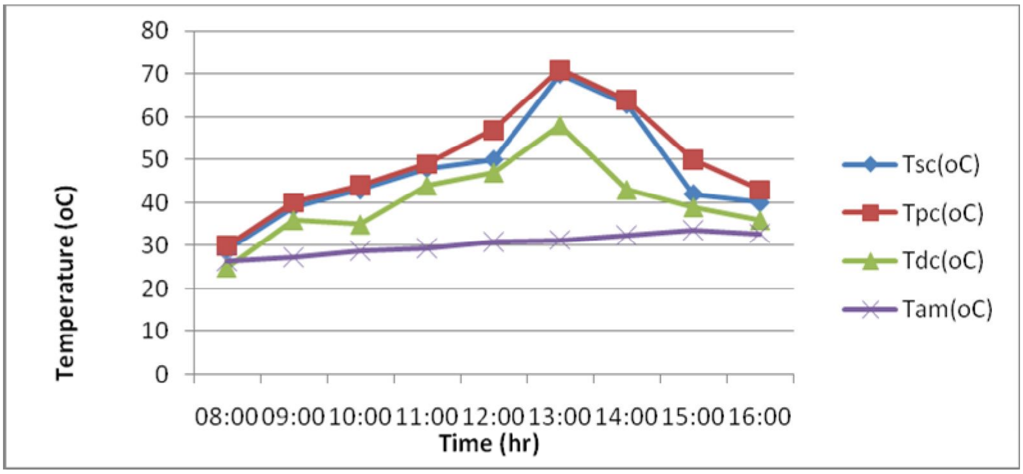

Figure 3a: Hourly variation of ambient (T_{am}), sprayed collector (T_{sc}), Painted collector (T_{pc}) and drying chamber (T_{dc}) temperatures on 08/11/2012

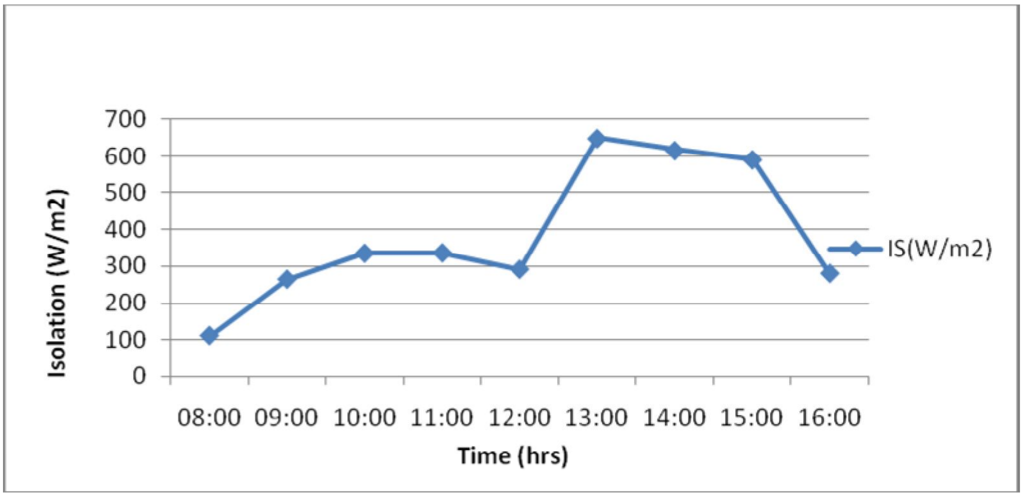

Figure 3b: Hourly variation of insolation on 08/11/2012 (See Appendix A)

Figures 3a reveal the temperature variation of sprayed collector (T_{sc}), painted collector (T_{pc}), dry chamber (T_{dc}) ambient temperature (T_{am}) with respect to variation in insolation shown in Figure 3b. As indicated in Figure 3a above, the heating temperatures of the painted collector (Tpc) were the highest throughout the test while the ambient temperatures were the least.
Figure 3b show the corresponding variation in insolation. High insolation leads to high ambient temperature and the temperatures of solar dryer as well. High wind speed caused more heat loss from solar dryer and low humidity outside the dryer speeds-up the moisture removal from solar dryer.

Table 3: Solar dryer without Yam (Preliminary Experiment, Day 3)

Time (hr)	T_{sc} (^oC)	T_{pc} (^oC)	T_{dc} (^oC)	T_{am} (^oC)	Insol. (W/m^2)
8.00	28.0	29.0	27.0	25.9	164.0
9.00	36.0	38.0	36.0	27.4	244.0
10.00	51.0	53.0	51.0	28.7	555.0
11.00	48.0	49.0	43.0	30.6	480.0
12.00	43.0	45.0	39.0	31.7	195.0
13.00	62.0	63.0	45.0	34.1	806.0
14.00	65.0	68.0	52.0	34.5	763.0
15.00	48.0	50.0	43.0	33.6	206.0
16.00	37.0	38.0	36.0	30.4	102.0
Total	418	433	372	276.9	3515.0

Analysis Results

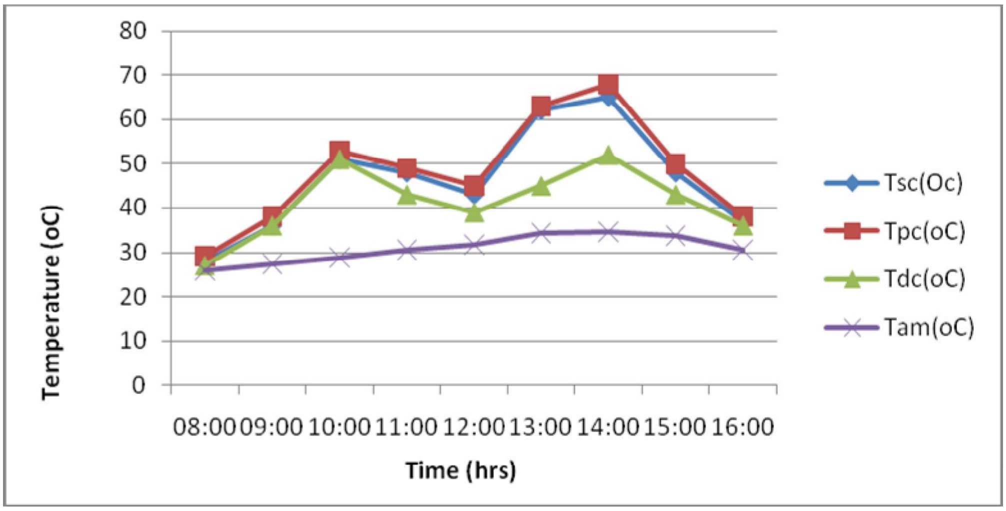

Figure 4a: Hourly variation of ambient (T_{am}), sprayed collector (T_{sc}), Painted collector (T_{pc}) and drying chamber (T_{dc}) temperatures on 09/11/2012

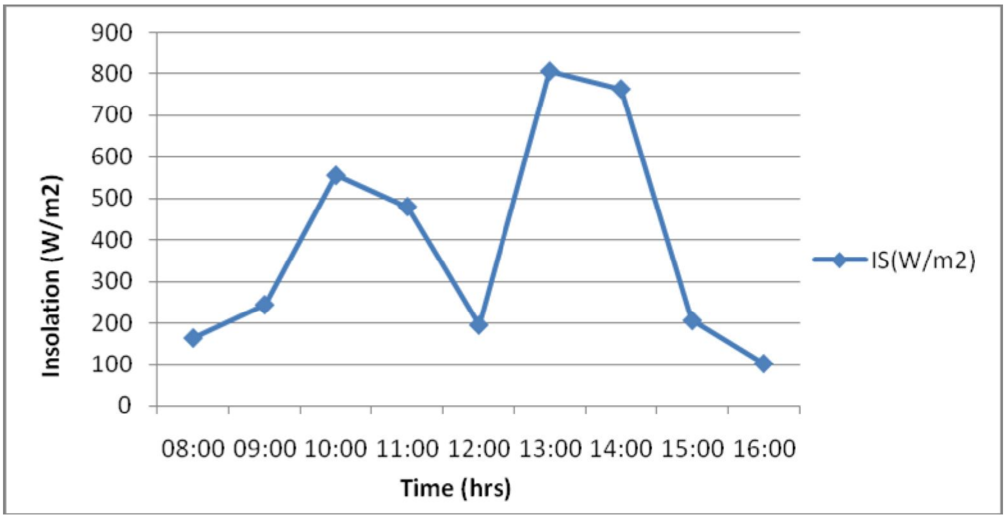

Figure 4b: Hourly variation of insolation on 09/11/2012 (See Appendix A)

As shown by Figure 4a, the heating temperatures of painted collector (T_{pc}) were higher than that of the other collector while the heating temperatures of drying chamber were greater than that of the ambient temperatures throughout the day. Figure 4b reveals the corresponding variation in insolation. As shown in Figures 4a and 4b the highest temperatures were observe between 1.00p.m and 3.00p.m when the insolation was highest.

Table 4: Solar dryer without Yam (Preliminary Experiment, Day 4)

Time (hr)	T_{sc} (^oC)	T_{pc} (^oC)	T_{dc} (^oC)	T_{am} (^oC)	Insol. (W/m^2)
8.00	27.0	27.0	28.0	25.1	258.0
9.00	44.0	45.0	46.0	28.4	416.0
10.00	50.0	52.0	50.0	30.4	614.0
11.00	55.0	57.0	53.0	32.3	498.0
12.00	67.0	70.0	57.0	33.4	126.0
13.00	76.0	79.0	60.0	34.4	678.0
14.00	71.0	76.0	56.0	35.1	707.0
15.00	57.0	58.0	42.0	35.0	575.0
16.00	53.0	47.0	38.0	34.9	451.0
Total	500	511	430	289.	4323.0

Results

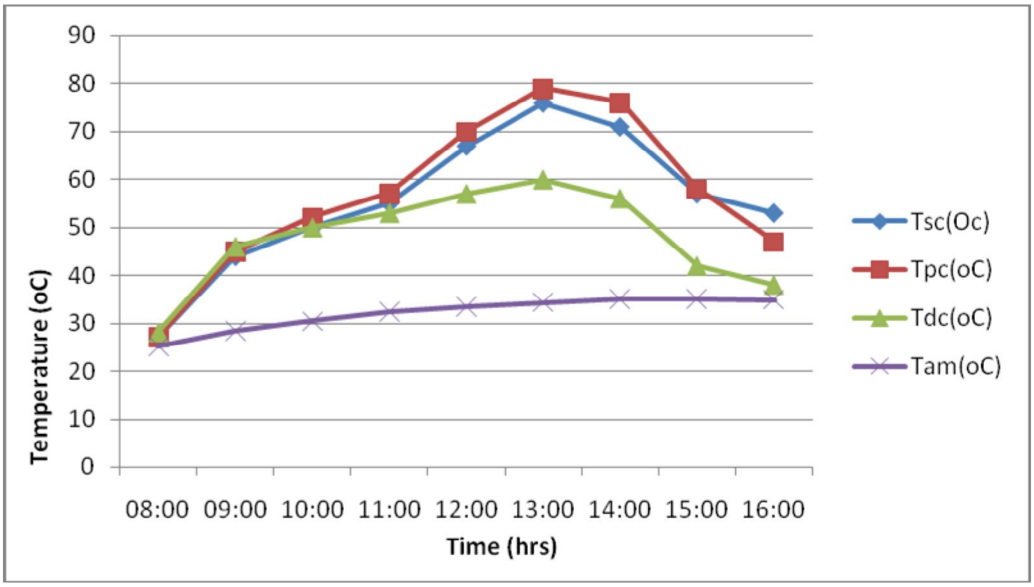

Figure 5a: Hourly variation of ambient (T_{am}), sprayed collector (T_{sc}), Painted collector (T_{pc}) and drying chamber (T_{dc}) temperatures on 10/11/2012

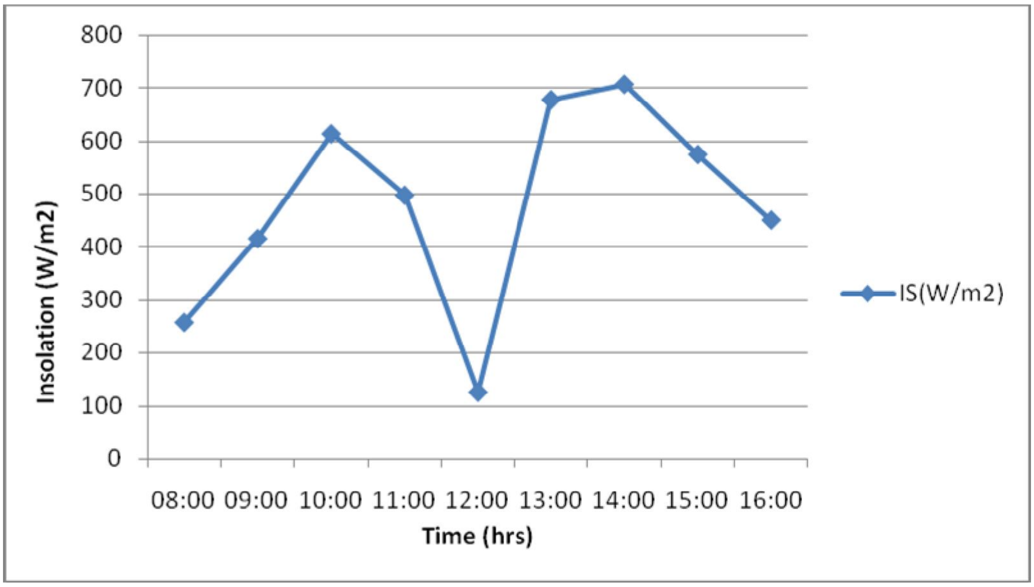

Figure 5b: Hourly variation of insolation on 10/11/2012 (See Appendix A)

Figure 5a reveals that the temperature variation of sprayed collector (T_{sc}), painted collector (T_{pc}) and dry chamber (T_{dc}) with respect to variation in ambient temperature (T_{am}). As depicted in Figure 5a, the heating temperatures of the painted collector (T_{pc}) were the highest throughout the test period while the ambient temperature (T_{am}) was the least. Figure 5b reveals the corresponding variation in insolation.

In summary, Table 5 shows the average total, average minimum and average maximum temperatures measured for sprayed collector (T_{sc}), painted collector (T_{pc}), drying chamber (T_{dc}) and ambient temperature (T_{am}) respectively during the whole test period.

Table 5: Average total, average minimum, average maximum and ambient temperature recorded during the load test period

Averages	T_{sc} (^{0}C)	T_{pc} (^{0}C)	T_{dc} (^{0}C)	T_{am} (^{0}C)
Average Tot.	50.50	53.30	44.30	31.10
Average Mini	27.30	28.00	25.50	25.90
Average Max	69.30	72.00	57.30	34.40

As indicated in Table 5, the average total, average minimum and maximum temperatures of the painted collector (T_{pc}) were greater than that of the sprayed collector (T_{sc}) while the average total, average minimum and maximum of drying chamber temperature were higher than that of the ambient temperature (T_{am}). These reveals that the painted collector (T_{pc}) is better than sprayed collector (T_{sc}) in-terms of heat absorber and the drying chamber of the solar dryer can dry food items faster than the ambient temperature. Physics behind this is that; dull surface (painted collector) absorbed and emit more energy than the highly punished one (sprayed collector). Also, the green house effect of drying chamber (Solar dryer) is greater than that of outside environment. Generally, this implies higher prospect for moisture removal in solar dryer than open sun-drying.

Conclusion

A prototype solar dryer was designed, constructed and tested based on preliminary investigations with tuber crops (yam slices) drying under controlled conditions (laboratory dryer). The constructed solar dryer can to be used to dry yam slices under controlled and protected conditions. The dryer with a collector area of 6.8m^2 is expected to dry 83.6 kg fresh yam slices from 66.39% to 0.99% moisture content in two days under ambient temperature during harvesting period from October to November. The dryer with 6.8m^2 collector area was designed and constructed as a prototype to be used in experimental drying tests.

This prototype solar dryer can function on both clear and cloudy weather condition. The solar dryer makes use of solar energy to heat-up air meant for drying food items, which helps to minimize the post-harvest and storage loss and in turn, makes the transportation of such dried foodstuff easy. The capital cost involved in the construction of the natural convection solar dryer is much lower than that of a mechanical solar dryer of the same size. Thus, the solar dryer is affordable to local farmers, most especially peasants in Niger State. Application of solar dryer by Niger State farmers can reduce post-harvest and storage losses, which contribute to food shortages, since it can be used for wide range of agricultural produce. The constructed solar drier has a wide range of possible applications in drying of foodstuffs (generally tuber crops). The solar dryer was able to raise ambient temperature to a considerable high-level throughout the period of the experiment (by retaining energy transmitted for a reasonable period) and this can increase the drying rate of foodstuff in the solar system (see Table 1).

The prototype constructed solar dryer was designed with rural farmers in mind; in locations where electrical power is available, the performance can be improved by electrically driven fans near the inlet to the collector (which naturally should increase the airflow into collector).

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Appendix A

Meteorological Weather Data

Date	Time (hrs)	Temp. (^{o}c)	Humidity	Wind S. (m/s)	Insolation (Wm^{-2})
07/11/2012	08:00AM	26.30	81.00	22.80	235.00
,,	09:00AM	28.70	73.00	23.40	452.00
,,	10:00AM	30.20	67.00	23.40	692.00
,,	11:00AM	30.20	67.00	23.40	236.00
,,	12:00PM	32.60	62.00	24.30	192.00
,,	01:00PM	32.80	58.00	23.40	736.00
,,	02:00PM	34.30	53.00	23.30	784.00
,,	03:00PM	34.10	48.00	21.50	477.00
,,	04:00PM	33.60	50.00	22.70	190.00
08/11/2012	08:00AM	26.30	82.00	23.00	110.00
,,	09:00AM	27.20	79.00	23.30	264.00
,,	10:00AM	28.80	75.00	23.90	335.00
,,	11:00AM	29.30	68.00	22.80	336.00
,,	12:00PM	30.90	63.00	23.00	291.00
,,	01:00PM	31.30	62.00	23.20	649.00
,,	02:00PM	32.30	55.00	22.10	616.00
,,	03:00PM	33.60	51.00	22.10	591.00
,,	04:00PM	32.80	53.00	22.00	280.00
09/11/2012	08:00AM	25.90	84.00	23.00	164.00
,,	09:00AM	27.40	78.00	23.30	244.00
,,	10:00AM	28.70	72.00	32.30	554.00
,,	11:00AM	30.60	68.00	24.00	480.00
,,	12:00PM	31.70	59.00	22.70	195.00
,,	01:00PM	34.10	52.00	22.90	806.00
,,	02:00PM	34.50	45.00	20.80	763.00
,,	03:00PM	33.60	51.00	22.00	206.00
,,	04:00PM	30.40	58.00	21.20	102.00
10/11/2012	08:00AM	25.10	86.00	22.50	258.00
,,	09:00AM	28.40	74.00	23.40	416.00
,,	10:00AM	30.40	53.00	19.80	614.00
,,	11:00AM	32.30	47.00	19.50	498.00
,,	12:00PM	33.40	36.00	16.30	126.00
,,	01:00PM	34.40	29.00	13.80	678.00
,,	02:00PM	35.10	26.00	12.70	707.00
,,	03:00PM	35.00	27.00	13.20	575.00
10/11/2012	04:00PM	34.90	29.00	14.30	451.00
Total	-	1121.20	2121.00	771.20	15304.00
Average	-	31.14	58.92	21.42	425.11

Source: Federal University of Technology, Physics Department, Bosso Campus, Minna, Niger state