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Full Length Research Paper

Construction and Performance Evaluation of a Passive Solar Crop Dryer with Two Stage Collector

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Abstract

Passive solar dryer plays an important role in postharvest handling of food processing and preservation in Africa. The passive solar crop dryer with two-stage collector was constructed at the workshop of the College of Agriculture, Science and Technology, Lafia using locally available materials. The performance of the dryer was evaluated. The temperature of the solar house, collector (absorber), dryer unit, ambient and wet bulb were undertaken hourly between the hours of 0900h to 0500h. The wind speed was also measured hourly to know the environmental air flow which average flow was 1.06m/s. Sample of marsh cassava of 8kg each was dried in the dryer and on the sun for comparative purposes. The dryer and sun-drying rates were 1.131kg/day and 1.22kg/day respectively. The mean temperature elevation (ΔT_{shd}, ΔT_{sha} and ΔT_{shc} were 5.4^{0}C, 5.9^{0}C and 4.7^{0}C respectively). The cassava marsh dried in the dryer with the initial moisture content of 50.9% to 8.4%. The pickup, system and collector efficiencies were 5.1%, 4.9% and 59% respectively. The sun drying sample was moved to a safe place daily while dryer sample was left in the dryer well protected. Passive solar dryer reduces drying time and improve the quality of the crop.

Keywords: *construction, performance evaluation, passive solar crop dryer, moisture content, Lafia, Nigeria*

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1.0 INTRODUCTION

Late harvesting of crops often results in over-maturity, leading to increased shattering losses, while early harvesting may promote mould development due to high moisture content in the harvested produce. Timely harvesting is therefore essential to minimise postharvest losses and preserve crop quality. In many rural communities, crops are harvested earlier than necessary, taking advantage of favourable solar conditions for drying, which can prolong storage. However, weather conditions are not always conducive to open-air drying, and harvested produce may deteriorate rapidly if not promptly processed. This makes efficient drying technologies essential to maintain product quality and reduce postharvest waste, especially for moisture-rich crops such as cassava, maize, and leafy vegetables (Fudholi et al., 2020).

Open sun drying remains one of the most widely used methods for crop preservation in sub-Saharan Africa because it is cost-free and simple to implement. The method dehydrates crops effectively by reducing their moisture content to levels that inhibit microbial activity and enzymatic degradation. However, despite its advantages, open sun drying is plagued by significant drawbacks, including contamination from dust, debris, animal droppings, and insect infestations, as well as losses caused by sudden rainfalls. Farmers in rural areas, aware of these shortcomings, nevertheless often dry crops on roadsides, rooftops, rocks, and untreated surfaces, thereby exposing them to multiple health hazards. These practices compromise food safety, reduce market value, and increase the risk of aflatoxin contamination, which has been linked to serious health concerns (Itodo & Fulani, 2004; Adeboye et al., 2019).

To address these limitations, a range of solar drying technologies has been developed. Solar dryers, which harness the sun's energy to create controlled drying conditions, can significantly accelerate drying rates while maintaining higher product quality than open-air methods. Among renewable energy technologies, solar drying is particularly promising because of the abundance and inexhaustibility of solar radiation in many tropical and subtropical regions. In addition to reducing crop losses, solar dryers contribute to sustainable agricultural practices by minimising dependence on fossil fuels (Azubuike et al., 2022; Leon et al., 2002). Moreover, solar dryers offer the possibility of year-round drying regardless of seasonal fluctuations in weather, thus enhancing food security and income generation for smallholder farmers.

Nigeria enjoys abundant sunshine throughout the year, with an average solar radiation intensity of up to 4.9 kWh/m²/day (Bamiro & Ideriah, 1982; Okonkwo & Nwoke, 2021). Well-designed solar drying systems can effectively harness this vast resource for postharvest processing. The performance of a solar dryer, however, is influenced by several factors, including local climatic conditions, the orientation and tilt angle of the collector, the thickness and transmissivity of the glazing material, wind speed, and the thermal conductivity of the absorber plate. Improvements in design, such as using two-stage collectors or integrating thermal energy storage, have been shown to enhance efficiency and maintain higher drying temperatures, especially during intermittent cloud cover (Ekechukwu & Norton, 1999; Yahya et al., 2022).

The design and construction of a passive solar dryer with a two-stage collector represent a significant innovation aimed at improving the temperature profile inside the drying chamber. The addition of a secondary collector—often referred to as a solar house—downstream of the primary collector allows for sequential heating of the air, resulting in a higher overall drying temperature than a single-stage design. This not only reduces drying time but also improves the microbiological safety and organoleptic quality of the dried product (Hossain & Bala, 2007). Furthermore, using locally available materials for construction enhances affordability and encourages adoption among small-scale farmers, aligning with rural development and poverty alleviation goals.

The present study focuses on the construction and performance evaluation of a passive solar crop dryer with a two-stage collector, designed using readily available local materials in Lafia, Nigeria. Its performance was compared with conventional open sun drying, using cassava mash as the test crop. The work addresses a critical gap in the adoption of efficient drying technologies in rural Nigerian communities by providing empirical evidence on temperature elevations, drying rates, and energy utilisation efficiency. By demonstrating the feasibility and benefits of the design, this research contributes to the growing body of knowledge on sustainable postharvest technologies, with potential applications for a wide range of crops in similar agroecological zones.

1.1 Objectives of the Study.

1. To construct a passive solar crop dryer with two stage collector using locally available materials.
2. To evaluate parameters such as temperature, drying rate, wind speed and efficiency of the dryer.
3. Reduce drying time and improve the quality of the crop.

2.0 MATERIALS AND METHOD

2.1 Description of the Passive Solar Crop dryer

Plat 1 is the diagram of the two stage passive dryer under construction. The first stage is the solar house which opens into second stage collector (primary collector) that slopes 18.5^0 to the horizontal and south facing. Plate 3 and 4 are the cassava marsh being dried in the dryer and on the sun respectively.

The solar house measures 1.94m, 1.51m, and 2m in length width and height respectively with the collector area of 19.66m^2 and volume of 5.86m^3. The solar house was built of timbers of thickness of 50mm as the frame, and the floor was made up of ply wood. The solar house was covered with 1.0mm transparent polythene films as the walls and the roof. The primary collector has an absorber cover with 1mm thickness of transparent polythene film. The dryer unit which is an extension of the primary unit measures 0.59m in length and 0.67m in width. The area is 2.88m^2, and the volume is 0.33m^3. The height was 0.83m and was also covered with polythene films which enable it to receive insulation from sun light in addition to the heat transfer to it from the solar house. The dryer is raised from the ground level 30cm by bricks. The length of the absorber unit is 1.46m width of 0.5 and the height of 0.83m with the area and volume of 5.13m^2 and 0.715m^3 respectively.

The absorber material was corrugated iron sheet painted black. Crops were held in a tray with knobs to enable it to be moved in and out of dryer for measurement.

Table 1, is a compilation of the dryer specification

The length of the door is 0.59m, width of 0.38m the area of the door is 0.22m^2.

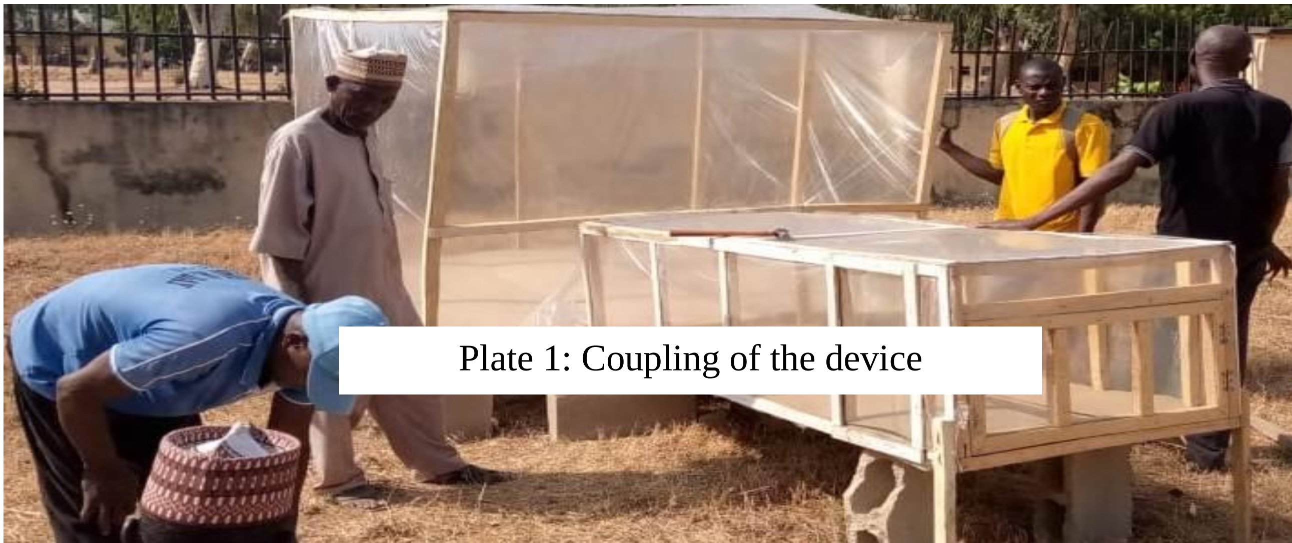

Plate 1: Coupling of the device

Plate 2: Sample of cassava marsh drying in the dryer

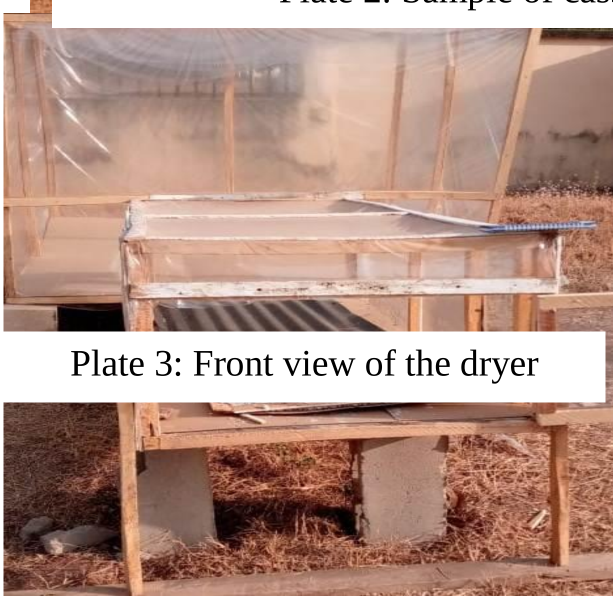

Plate 3: Front view of the dryer

Plate 4: Cassava marsh drying on the sun

2.2 Construction of the Dryer

The wood materials for construction were purchased from Lafia Timber Shade, while the plywood, bricks, nails, and polythene fibres were purchased from Lafia Market.

The wood was cut according to specification and joined together, forming a frame network, while the absorber and drying unit were also cut according to specification and joined together by nails. Both the solar house and the drying unit were separate.

The solar house was mounted on the bricks raised above the ground level, while the absorber and drying unit, which was a compartment, were connected to the solar house through the opening. The absorber and dryer were raised 18.50 facing south. This is to enable it to trap sunlight at a right angle, i.e., for maximum insulation.

Table 1: Summary of dryer specification

S/N	Units	Parameters				
		Length	Width	Height	Volume	Area
1.	Solar house	1.94m	1.51m	2m	5.86m^3	19.66m^2
2.	Primary collector	2.13m	1.92m	0.83m	1.143m^3	7.03m^2
	a) Absorber material (corrugated iron sheet painted black)					
	b) Cover material slope	1.46m	0.59m	0.83m	0.715m	5.13m
3.	Dryer	0.67m	0.59m	0.83m	0.33m^2	2.88
4.	Stand					
	1) Solar house	0.41m				
	2) Primary house	0.47m				
5.	Door	0.59m				0.22m
6.	Depth of the commodity					50mm

2.3 Analysis of the Passive Solar Dryer

i) Heat energy available to the solar house.

The heat energy available to the solar house was computed from the equation 1 (Duffie and Beckman, 1980)

$HEA = \eta A_{sh} G C_p \Delta T_{sha}$ ………………………….,…….. 1

ii) Area of solar house

The area of the solar was computed from equation 2

$A_{sh} = HEA/\eta G C_p \Delta T_{sha}$ ………………………….…. 2

iii) Pressure drop across the system

The pressure drop across the system was computed from equation 3

$\Delta P = \Delta P_{sh} \ \Delta P_c + \Delta P_d$,,,,…………………………… 3

2.3.1 Evaluation of the Dryer

The dryer was constructed and evaluated at the works Department of College of Agriculture, Science and Technology, Lafia, Nasarawa State. To determine the air temperature in the Solar house, absorber, dryer and ambient temperature on hourly basis during the hours of sun shine from 9:00am to 5:00pm from mercury in bulb thermometer which were installed in each unit. 8kg of mashed cassava of 45mm thick was dried in the sun and dryer for comparative purpose. They were measured hourly until no further weight loss. The initial and final moisture content of the cassava marsh was determined by oven drying method.

The ambient temperature and wind speed were also measured hourly using mercury in bulb thermometer and cup anemometer respectively.

Collection, system drying and pickup efficiencies were calculated from equation 4, 5, and 6 respectively.

$\eta_c = [V\rho \Delta T C_P / A_c I_c] \times 100\%$ ……………………………. 5

$\eta_d = [WL/I_c A_c t]\ 100\%$ …………………………………... 6

$\eta = [M_o - M_t / V\rho t(h_{as} - h_i] \times 100\%$ …………………….. 7

2.3.2 Moisture Content

The moisture content which is the amount of water present in the sample under examination is expressed as a percentage of the sample. It is expressed either in wet basis or dry basis

$M_w = \frac{M_w}{M_s + M_m}$ x 100% equation 8

$= \frac{M_w}{W_s}$ x 100% (Mohsenin, 1970)

Where:

W_w = weight of moisture

W_s = Weight of bone dry substance

2.3.3 Dry Rate

The dry rate which is the quantity of the material dried at a given time or quantity of water removed at a given time is given by dry rate = kg/time

The quantity of the material to dry was place in the drying chamber and the same quantity was place on the sun for comparative purpose. Readings were recorded from 09:00am to 5:00pm hourly until no change in weight of product occurred.

2.3.4 Drying Efficiency

This is the relationship which involves the heat utilized and the heat available for drying under the environmental condition that prevails. This efficiency is used when comparing the performance of dryers. Drying efficiency can be computed from equation 9

$\eta = \frac{WL}{I_c A_c t}$ ………….………………………………… 9

Where W = Weight (kg)

L = Latent heat of evaporation kg/kg or kJ/mol.

K = Intensity of solar radiation W/M^2
t = Drying time
A = The effective area of collector facing the sun (m^2)

2.3.5 Pickup Efficiency

This is the direct measure of how effectively the capacity of heated air to absorb moisture is utilized. This is the ratio of the moisture picked up by the air in the drying chamber to the theorty capacity of the air to absorp moisture.
The heat available to the solar house can be computed using the equation (Duffie and Beckman, 1980).

2.3.6 Heat Available to the Solar House

The heat available to the solar house can be computed using the equation 10 below.
$HEA = \eta AGC_p(T_{sh} - T_a)$ …………………………………… 10
Where η = efficiency of the solar house (%)
A = Collector area (m^2)
G = Collector fluid mass flow rate per unit collector area = 0.01682kg/m^{2}s (Itodo, 1993).
C_p = specific heat capacity of the collector fluid air at 24^{0}c = 1.005kj/kg^{0}c
T_{sh} = Temperature inside the solar house
T_a = Temperature outside the solar house

2.3.7 Collector Efficiency

The efficiency of the collector is determined from equation 11

$$\eta_c = \frac{1}{[1+U_1/]\left[1-e^{(U_oG_aC_p)[G_aC_p/U_o]fca}\right]}$$

(Whillier, 1964) ………………………………………….. 11

2.3.8 Collector Area

Collector area is computed from equation 12
$A_c = V\rho C_p\ \Delta T/\eta_c I_c$ …………………………………… 12
Where V = wind speed (m/s)
ρ=Density kg/m^3
I_c= Insolation on collector (1079w)m^2
C_p= Specific Capacity
A_c= Area of the collector
ΔT = Temperature elevation (^{0}C)

2.3.9 Pressure drop

The pressure drop across the first stage collector solar house and the primary collector was computed from equation.
$\Delta P_c = FIG_d/2\rho R_h$ ……………………………………….. 13

Where
F_a = effective transmissivity absorptivity produce
I = intensity of insolation on sloped collector surface, W/m^{2}s
G_d = mass flow rate of air per unit dust area
ρ = density (kg/m^3)
R_h = hydraulic radius

2.3.10 Angle of Tilt (β)

The angle of tilt (β) of the collector is given by the equation. Where, ∅ is the angle of latitude?
$\beta = 10^0$ + Lat. ∅ (Alamu *et al*., 2010) …………………. 14
The latitude of Lafia is 8.5 therefore, $\beta = 18.5^0$

3.0 RESULTS AND DISCUSSION

Table 2 is the mean record of data obtained from the field at different units of the dryer. The table represents day one, two and three, respectively.

The data obtained were the temperature readings of ambient, solar house, and absorber dryer and the weight of cassava mash dried in the sun and the dryer. The wind speed was determined using an anemometer.

The readings were recorded hourly from 9:00am to 5:00pm every day until there was no change in weight of the commodity being dried.

The initial weight of the commodity (cassava mash being dried) was 8 kg until the third day, when there was no longer a change in weight.

The average reading for the first, second, and third days seen in table 2 revealed that the absorber was able to raise the temperature above ambient temperature by 8.6°C and 8.33°C for the first and third days, respectively. The solar house was able to raise the temperature, which was delivered to the absorber in raising the temperature.

On the second day of the research, the wind speed was poor with intermittent sunshine, which was responsible for the low temperature and for the low drying rate. On the third day the temperature of the absorber was 4°C above the temperature of the solar house.

Kolebani, (2025) designed constructed and evaluated the performance of a passive solar dryer and record 750C and 280C temperature for dryer and ambient respectively. Umogbai and Iorter (2013) recorded the highest temperatures of 38°C, 59°C and 48°C for ambient, collector and the drying chamber, respectively.

Table 2: Mean of data obtained in the field for three days

S/N	Parameters	Day One	Day Two	Day Three
1	Solar house (^{0}C)	39.66	36	37
2	Absorber (^{0}C)	42.3	36.78	41
3	Dryer (^{0}C)	36	36.11	31.67
4	Ambient (^{0}C)	33.7	39.22	32.67
5	Dry thermometer (^{0}C)	54.6	54.3	52.4
6	Wet thermometer (^{0}C)	43	42.9	41.56
7	Wind speed (m^2)	1.19m/s	0.8	1.2
8	Sun dry weight (kg)	0.2kg	0.11	0.03
9	Dryer weight (kg)	0.167	0.08	0.04

The absorber has higher temperature because the temperature from solar house was delivered to it and it was responsible for this. The temperature of the dryer unit was lower because of the moisture raised as a result of drying. Hegde *et al*., (2015) evaluated the performance of a dryer and recorded the maximum temperature of 45^{0}C and 34^{0}C for dryer and ambient respectively.

Table 3: Summary of Temperature Elevation for the Three Days

S/N	Temperature Elevation (ΔT) ºC	Days	Time (hr)									Average
			9am	10am	11am	12 noon	1pm	2pm	3pm	4pm	5pm	ºC
1	ΔT_{sha}	1	9	8	8	8	6	2	3	3	6	5.9
		2	− 1	− 4	− 2	0	− 4	5	− 2	6	− 4	-3.1
		3	2	5	6	7	4	4	7	4	0	4.3
2	ΔT_{shc}	1	− 0	− 1	− 2	− 5	− 3	− 6	− 1	−10	− 5	− 3.7
		2	0	− 2	− 2	− 5	− 3	− 6	− 1	−2	−5	4.7
		3	−6	−6	−1	−3	−4	−4	−3	− 4	−7	−4.4
3	ΔT_{shd}	1	7	6	4	8	2	1	2	3	0	3.7
		2	−2	−0	−2	−1	0	−1	−1	−1	0	0.88
		3	2	5	8	7	6	7	7	4	2	5.4
4	ΔT_{ca}	1	9	10	10	3	9	8	−2	−5	−4	5.3
		2	−1	−3	−2	−1	−2	−2	−2	−5	−4	2.3
		3	8	9	7	10	8	8	10	8	7	8.3
5	ΔT_{cd}	1	7	8	6	13	5	7	1	5	5	6.3
		2	−1	1	2	0	−2	−2	−1	1	0	0
		3	8	9	9	10	10	11	10	8	9	9.3
6	ΔT_{da}	1	2	2	4	0	4	1	1	0	5	2.1
		2	1	−4	−4	−1	−4	−4	−3	−5	−4	3
		3	0	0	−2	0	−2	−3	0	0	−2	−1

Table 3 is the analysis of the temperature elevation for the three days. On the first day of the research, the mean temperature elevation of the solar house over the ambient was 5.9°C, which was well appreciated, as can be seen in table 3. The result of the average Tsha on the second day was -3.1°C, which was poor because of cloud cover. On the third day there was intense sunshine and wind, which was responsible for the average temperature of 4.3°C. Kilanko et al. (2019) recorded the temperature range of 2°C and 12°C over ambient, and Hegde et al. (2015) recorded an average Tsha of 10°C as against 5.90°C for this research. The average temperature elevation of the solar house over the collector Tshc for the three days was -3.7°C, 4.3°C and 4.4°C, which was not appreciated. This was because of poor airflow and sunshine. The collector raised the temperature above the temperature of the solar house. The temperature elevation of the solar house over the collector Tshc was less high than that of the collector for the three days under review, which accounts for the negative values.

The function of the solar house was to enhance the temperature of the collector (absorber) so that it can be used for drying. Bolaje and Olalushi (2008), as well as Adejumu and Bamgboye (2004), made similar observations in their work.

Tshd was observed on the first day and the third day to appreciate with average temperatures of 3.7°C and 5.4°C, respectively, because there was intense sunshine, as can be seen in table 3. Tshd on the second day was low (0.88°C), indicating that there was poor sunshine, which was responsible for this. The mean temperature of the collector over ambient (Tca) as observed from the table: the first day there was intense sunshine (5.3°C), and it was 8.3°C for the third day. On the second day, the temperature elevation of -2°C was low; there was poor sunshine as the ambient temperature was above the collector temperature. Itodo and Fulani (2004) made a similar observation. On the third day, the sunshine raised the temperature of the collector over ambient.

The temperature elevation of the collector over dryer Tcd was well appreciated on the first and third days. The second day, there was poor sunshine, which accounts for the negative values (Itodo et al., 2002, made a similar observation).

The temperature elevation of the dryer above ambient (Tda) from the table, the values obtained of 2.1, 3 and -1°C, are low because of the condensation of moisture at the dryer unit.

Expectedly, the values are supposed to be more than the ambient, but moisture condensation as well as poor sunshine was responsible for this. However, Fulani and Itodo (2004) recorded 30°C over the dryer for their similar observation in their work.

Table 4: Summary of the Drying Variables

S/N	Parameters	Mean	Day 1	Day 2	Day 3
1.	Air flow (m/s)	High	2.0	1.6	2.4
		Low	0.5	0.4	0.6
		Mean	1.25	1.0	1.4
2.	Ambient temperature (^{0}C)	High	40	42	36
		Low	31	32	30
		Mean	36	37	33
3	Temperature of collector (^{0}C)	High	46	42	44
		Low	41	32	38
		Mean	44	36	41
4	Ambient relative humidity (%)	High	68.16	56.90	65.30
		Low	46.86	46.86	48.04
		Mean	57.51	51.88	56.67
5	Air temperature at the outlet ^{0}C	High	41	39	34
		Low	32	33	30
		Mean	37	36	32
6	Crop weight (kg) (i) Dryer	Start	8.0	6.05	4.6
		End	6.5	5.3	4.6
	(ii) Sun dry	Start	8.0	5.7	4.6
		End	6.2	4.7	4.3
7	Moisture content (%) (i) (Dryer)	Start	50.9	30.07	13.9
		End	32.15	17.05	8.0
	(ii) Sun dry	Start	50.9	22.15	8.4
		End	28.5	9.65	4.5

Table 4 is a summary of drying variables. The highest air flow of 2.0m/s, 1.6m/s and 2.2m/s were recorded for day 1, 2, and 3 respectively.

The mean values as indicated in the table are significant to influence drying. Air flow is responsible for moisture removal.

The highest ambient temperature of 40^{0}C, 42^{0}C, and 36^{0}C recorded for 1st, 2nd, and 3rd day with their corresponding mean temperature value of 36^{o}C, 37^{o}C and 33^{o}C respectively during the period of the research depending on sun shine and the flow of the air this was responsible for the highest and lower value obtained which affects the drying rate of the dryer.

Table 5, is the profile of moisture content during drying. The dryer was able to reduce the moisture content from 50.9% to 8.4% on wet basis representing the drying rate of 1.22kg/day while sun drying was able to reduce the moisture from 50.9% to 4.5% wet basis representing the drying rate of 1.13kg/day. Adejumu and Bamgboye, (2004) used cassava as test material, the dryer was able to reduce the moisture content from 65.27% to 8.10%.

Azubuike *et al., (*2022) recorded a dry rate of 27.0g/day and 34g/day for sun drying and the dryer respectively. Evordius *et al.,* (2023) reported a dry rate of 1.85kg/hr and 1.88kg/hr using pineapple and carrots as test materials.

Table 5: Profile for moisture content of cassava marsh during drying Dryer and sun drying

S/N	Days	Time (hour)								
		9am	**10am**	**11am**	**12noon**	**1pm**	**2pm**	**3pm**	**4pm**	**5pm**
1	Sun	50.9	47.05	43.5	42.15	38.4	33.5	32.15	29.65	28.5
	Dryer	50.9	47.15	45.9	43.4	38.4	37.15	35.9	33.4	32.15
2	Sun	22.15	20.9	19.65	17.15	14.65	12.15	12.15	12.15	9.65
	Dryer	30.07	25.0	24.65	22.15	20.9	19.65	18.4	17.65	17.5
3	Sun	8.4	7.15	7.15	7.15	4.65	4.6	4.5	4.5	4.5
	Dryer	13.9	12.9	11.25	11.25	10.9	9.7	8.4	8.4	8.4

Figure 1, 2, and 3 were plotted base on the data in table 5 for day 1, 2 and 3 respectively

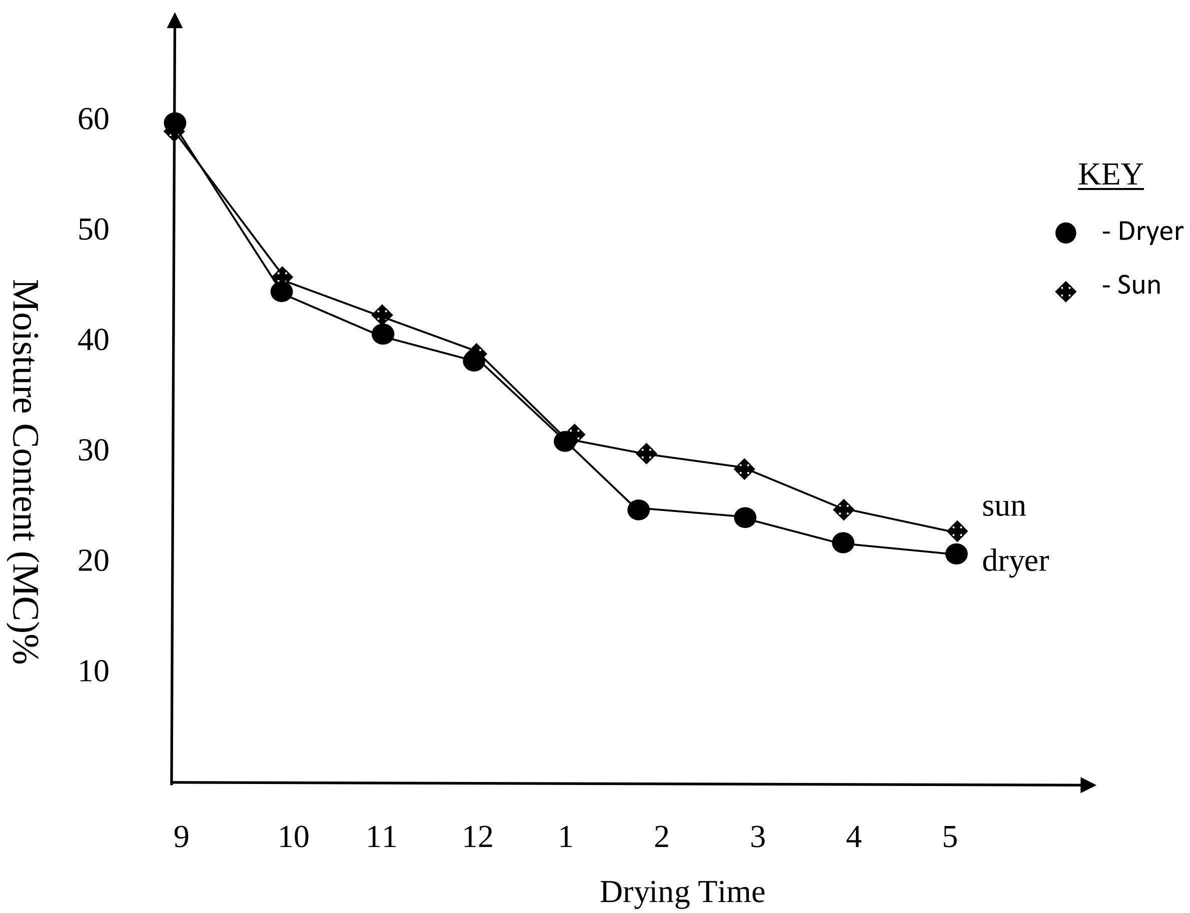

Fig. 1: moisture content versus time (Day 1)

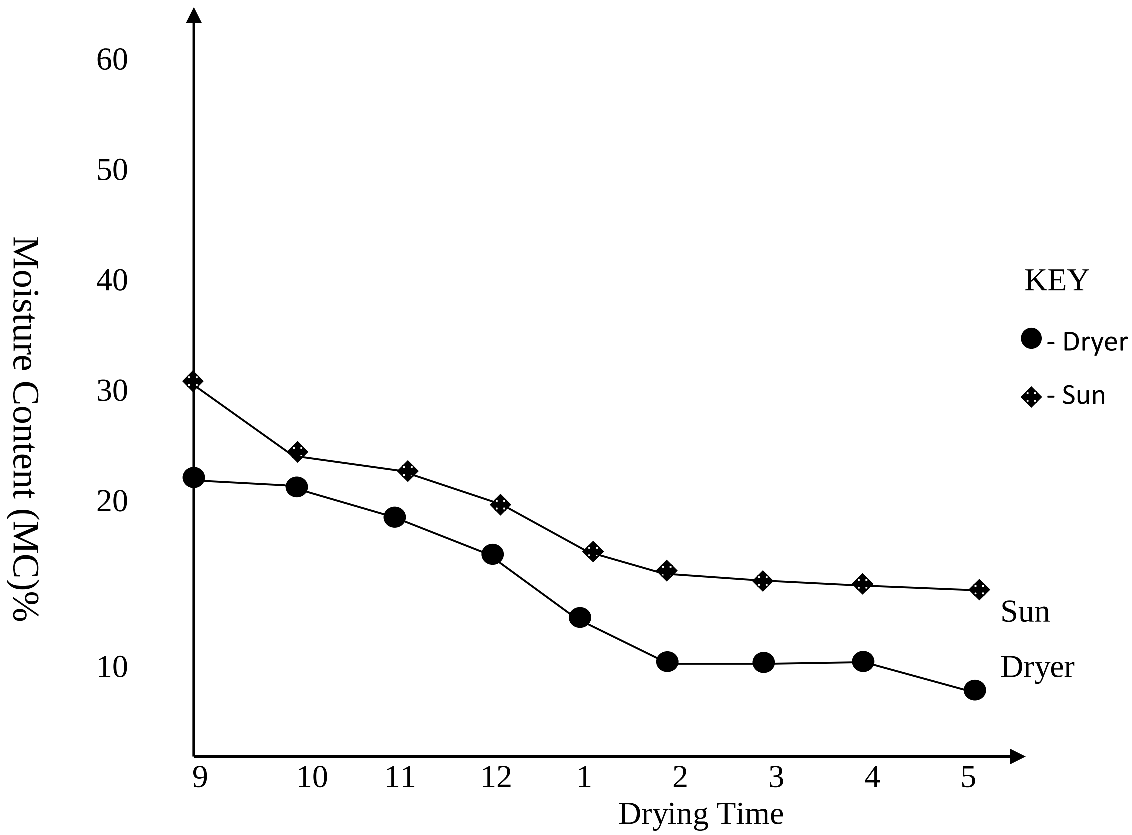

Fig. 2: moisture content versus time (Day 2)

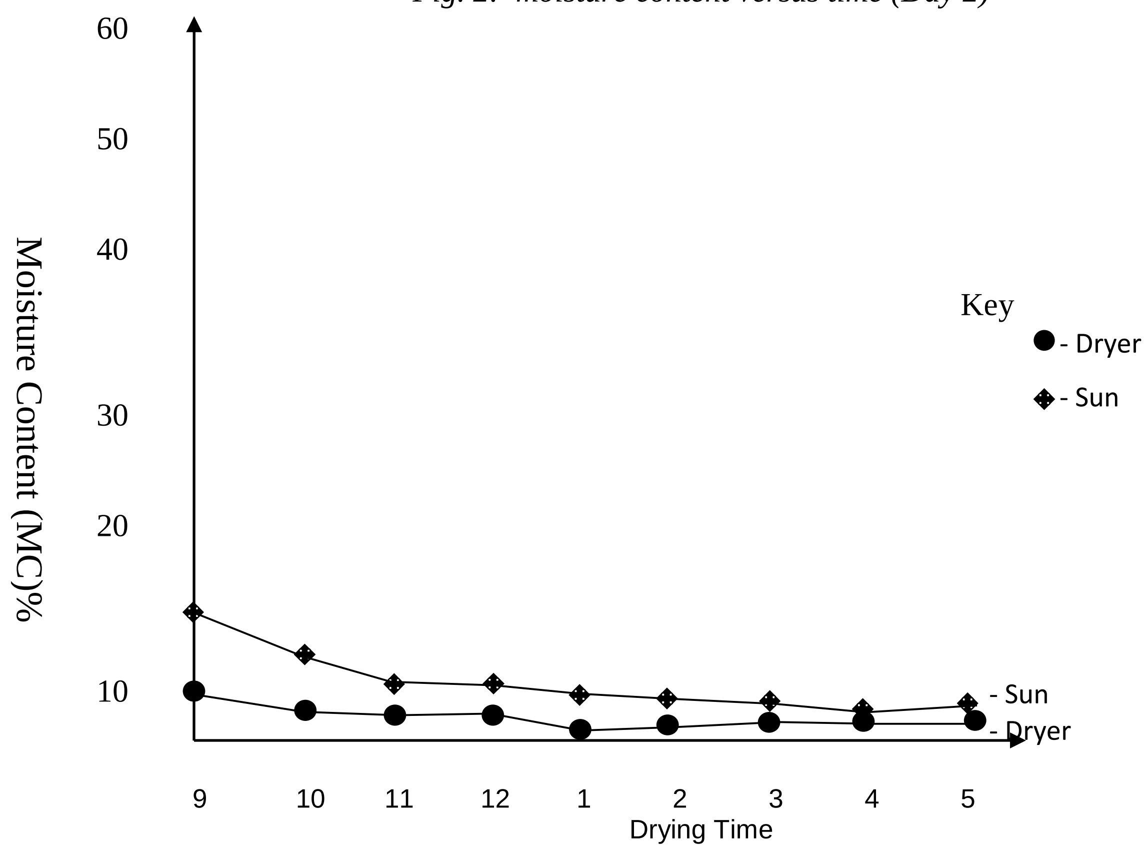

Fig. 3: moisture content versus time (Day 3)

Dryer performance are affected by weather condition. There was significant difference between the dryer and the open sun drying. Wind pressure aided the open sun drying to be higher than the dryer.
Table 6, is the drying rate profile during the period of drying. The dryer was able reduce the weight of the cassava marsh from 8kg to 4.6kg while the sun heat was able to reduce the mass of the cassava marsh from 8kg to 4.3kg. Figure four (4) is the corresponding weight reduction.
Sun drying rate is higher than the dryer rate which can be attributed to poor sun shine, poor air movement in the dryer and product characteristics.
This work is targeted at rural and village farmers who may not have access to electricity and other devices to enforced air through the device. To improve the flow of air as to increase drying a channel is needed in form of a blower.

Table 6: Reduction of weight profile

Days		9am	10am	11am	12noon	1pm	2pm	3pm	4pm	5pm
1	Dryer	8	7.7	7.6	7.4	7.0	6.9	6.8	6.6	6.2
	Sun	8	7.7	7.4	7.3	7.0	6.6	6.5	6.3	6.3
2	Dryer	6.05	6.0	5.9	5.7	5.6	5.5	5.4	5.3	5.3
	Sun	5.7	5.6	5.5	5.3	5.15	5.0	4.9	4.9	4.7
3	Dryer	5.0	4.95	4.9	4.9	4.8	4.8	4.7	4.65	4.6
	Sun	4.6	4.5	4.5	4.5	4.4	4.4	4.3	4.3	4.3

Table 7: Hourly Weight Loss Rate

Days		9am	10am	11am	12noon	1pm	2pm	3pm	4pm	5pm
1	Dryer	0	0.3	0.4	0.6	1.0	1.1	1.2	1.4	1.8
	Sun	0	0.3	0.6	0.7	1.0	1.3	1.5	1.7	1.7
2	Dryer	1.95	2.0	2.1	2.3	2.4	2.5	2.6	2.7	2.7
	Sun	2.3	2.4	2.5	2.7	2.85	3.0	3.1	3.1	3.3
3	Dryer	3.0	3.05	3.1	3.1	3.2	3.2	3.3	3.35	3.4
	Sun	3.4	3.5	3.5	3.5	3.6	3.6	3.7	3.7	3.7

Table 7 is the hourly weight loss in the dryer as well as on the sun for the three days. The dryer and the sun where able to remove 3.4kg and the 3.7kg of moisture respectively from 8kg of cassava marsh that was dried on each. The relative poor weather at the time of the experiment influenced the rate of drying. The result shown that sun drying is slightly higher than dryer. Also from figure 4 the rate of sun drying is higher than the dryer. The experiment is carryout on the 26th of March, 2025 when the raining season has started. These unsteady factors affected drying.

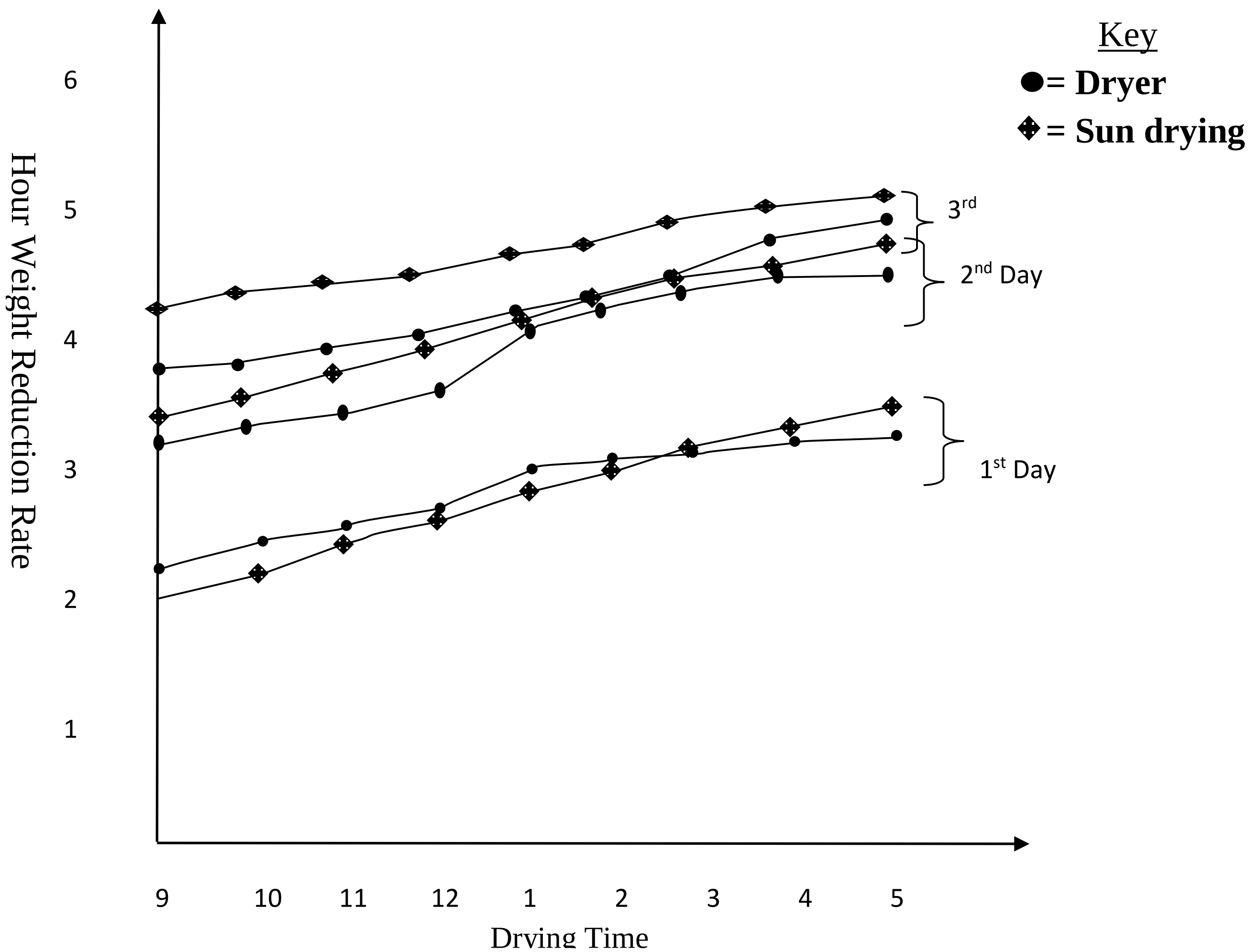

Figure 4: is the Corresponding Curve for Weight Reduction Rate

Table 8: Hourly Moisture Loss

Days	Parameters	Time (hours)								
		09	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1st	Dryer	0.0	3.75	5	7.5	12.5	13.75	15	17.5	18.7
	Sun	0.0	3.85	7.4	8.75	12.5	17.4	18.75	21.25	22.4
2nd	Dryer	20.85	25.9	26.25	28.75	30	31.25	32.5	33.4	33.75
	Sun	28.75	30	31.25	33.75	36.25	38.75	38.7	38.75	41.25
3rd	Dryer	38	39.65	39.65	39.65	40	41.2	42.4	43	43.5
	Sun	43.75	43.75	43.75	43.75	44.2	44.3	44.7	44.9	45

From figure 5 moisture loss of the commodity dried on the sun was higher than the commodity dried in the dryer. The performance of this Crop Solar Dryer Depend on the temperature, product characteristic (moisture content), air velocity environmental and climate condition. The passive crop solar dryer among many may be affected by some of the factors listed above.

4.0 CONCLUSION AND RECOMMENDATIONS

The two stage passive solar crop dryer was constructed and evaluated to be recommended to rural farmers where drying is actually poorly carried out.

The drying rate for the dryer and sun drying were 1.13kg/day and 1.22kg/day respectively which may be low, but more preferably than open sun drying because it return nutritional quality better them traditional sun drying. The collection, drying and picking up efficiencies were 59%, 4.9% and 5.1% respectively.

By the use of the second stage collector a temperature elevation of 8^0C above is achieved in the dryer. The poor rate of drying can be improved by opening a duct in the solar house in the direction of air to improve air flow. The dryer housed the crop. Also an absorber can be introduced in the solar house to raise the temperature.

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LIST OF SYMBOLS

ΔT_{sha} Temperature elevation of solar house over ambient (0C)
ΔT_{sha} Temperature elevation of solar house over the primary collector (0C)
ΔT_{shd} Temperature elevation of solar house over dryer (0C)
ΔT_{ca} Temperature elevation of primary collector over ambient (0C)
ΔT_{cd} Temperature elevation of primary collector over drying unit (0C)
ΔT_{da} Temperature elevation of drying unit over ambient (0C)
ΔT Temperature raised
Cp Specific heat of air (kj/kgK)
Uo Overall heat transfer coeffiencient (W/m2K)
Ul Collector heat loss coefficient (W/m2K)
Ga Mass flow rate per unit collector area
Fca Effective transmisivity absorptivity product
Gd Mass flow rate of air per unit duct area
Rh Hydraulic radius m
Wi Initial weight of crop (kg)
Wf Final weight of crop (kg)
Ac Area of collector (m2)
Ic Insolation on collector surface (W/m2)
W Mass of moisture evaporated (kg) in time t
t Drying time, s
L Latent heat of evaporation of water, (kJ/kg)
has Adiabatic saturation humidity of the air entering the dryer
hi Absolute humidity of air entering the dryer
ψ Azimuth angle
Ash Area of Solar house (m2)
ρ Density (kg/m3)
W Mass of moisture removed from the dryer (kg)
Mo Initial mass to be dried (kg)
Mt Final weight (kg)
ω Hour angle
n Day number
δ Angle of declination
β Slope angle
θh Angle of incidence of radiation on horizontal surface
Ih Intensity of insolation on sloped collector surface (W/m2s)
θ Angle of incidence of radiation on horizontal surface
Is Intensity of insolation on sloped collector surface (W/m2s)
ΔI Increase of Is over Ih
Δ Percentage increase of Is over Ih
η Efficiency of solar house, (%)
ηc Collection efficiency (%)
ηp Pick-up efficiency (%)
ηd System drying efficiency (%)