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Development of a Solar Collector for Agricultural Products Drying

Onyekachi, C.P.,[1] Obetta, S.E.[1] and Igila, S.S.[1]
[1]Department of Agricultural and Environmental Engineering, Joseph Sarwuan Tarka University, Makurdi, Benue State

Abstract:- Development of a solar collector for drying agricultural products, particularly vegetables, was designed, constructed and evaluated. The primary objective of the study was to tackle the issue prevalent in many existing solar dryers, which are predominantly stationary and consequently fail to optimize their power output potential. Therefore, a solar tracking device was formulated and constructed to trace the sun's trajectory, ensuring the generation of the highest attainable power and increase the energy harvested and thereby optimizing the amount of energy received. The drying apparatus primarily comprises a solar collector, a solar tracking device, drying chamber and chimney The size of the collector considered was 1219 mm x 609 mm, comprising a single-layer glass with a thickness of 4 mm, a black-painted aluminum absorber plate measuring 2 mm in thickness, and an insulation material with thickness of 3 mm which was enclosed within a wooden casing. The drying chamber was made of highly polished wood frame and covered with plywood, consisting of three drying trays. A 200–W wiper engine that swings a collector configuration was adapted and this 200 watts motor wiper makes it possible for the collector to attain 150^0 rotation in a full wipe. Equipped with a sensor that is calibrated to allow a track of 30 degrees in 120 minutes; in that way, optimum and down times are appropriately captured. In assessing the various conducted tests, the performance parameters considered for evaluation comprised temperature, moisture content of the produce, collector and drying efficiencies, drying period, and drying rate. The moisture content of okra experienced a reduction from 87 % (w.b,), 7.0 g H_2O/g solids(d.b) to 13% (w.b), 0.1 g H_2O/g solids(d.b) respectively and the moisture content of pepper experienced a reduction from 83 % (w.b), 4.89 g H_2O/g solids(d.b) to 17 % (w.b), 0.03 g H_2O/g solids (d.b) respectively in a span of two to four days. The drying rate for okra was identified to be 2.00 (g H_2O/g solids)/h whereas for pepper it was 0.67(g H_2O/g solids)/h. The collector efficiency was identified to be 25.24 % and Drying efficiency was also identified to be 28.67%. The drying curves, typical of thin layer type, produced during the drying process, followed definite pattern irrespective of the trays in the drying chamber. With the polynomial behaviour, their equations, typical of Okra was $y = 0.3056x^2 - 7.0526x + 43.633$ and R^2 were estimated highly with correlation coefficient (R^2) ranging from 91 to 99%, and for Pepper as: $y = 0.61x^2 - 10.166x + 46.168$ and R^2 values ranged from 83 – 94% - a measure of theoretical correctness. These high values of correlation coefficients obtained from the drying curves bore reasonable closeness between the experiment and theory. In all, these 2nd order equation models of these curves, described the behaviour of the drying process. This work provided a good insight into what possibilities local technologies can do. The products of drying displayed showed good indices of acceptability, attainment of shelf-life moisture content, and showing aesthetic and commercial appeals.

I. INTRODUCTION

Heat and electricity are created when solar energy is collected from solar radiation. When compared to other resources and forms of energy, it is a clean, affordable, renewable resource with lower levels of pollution (Ahhmad *et al.*, 2010). The primary source of energy in our solar system is the sun. Massive amounts of energy are created by the sun's ongoing nuclear fusion process in its core; only a small portion of this energy reaches Earth and supports life as we know it. All natural cycles and activities, including photosynthesis, wind, rain, and ocean currents, are brought about by solar radiation and are essential to life (Bahloul *et al*., 2009).

One possible decentralized thermal use of solar energy is solar drying, which is especially useful in developing nations (Sharma *et al.,* 2009). The process of solar drying is commonly distinguished from "sun drying" by the utilization of apparatus to gather solar radiation and utilize the resulting radiative energy for drying purposes. In many nations, sun drying is a typical method of farming and agriculture, especially when the outside temperature exceeds 30 ºC or higher. There are a number of established drawbacks to sun drying crops for large-scale production, including crop damage from animals, birds, and rodents; quality deterioration from direct sun exposure; and contamination from dirt, dust, or debris. Additionally, this system requires a lot of labor and time because crops need to be covered at night and during inclement weather in order to prevent domestic animal attacks. Because of the uneven drying process, there is also a potential for insect infestation and the growth of microorganisms. Solar drying systems, which dry things inside of closed systems with greater internal temperatures, are a development in sun drying. In addition, direct sun exposure on days with high temperatures may result in case hardening, a process where an outside hard shell forms around agricultural products, trapping moisture inside. As a result, using solar dryers allows for the efficient

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use of the sun's energy while maintaining high product quality through careful management of radiative heat.

Around the world, farmers have been using solar energy to dry goods including grains, fruits, meat, vegetables, and fish to boost the quality of their produce by reducing postharvest losses. To reduce postharvest losses, low-cost solar dryers that are manufactured locally must be produced using economical and efficient drying techniques (Weiss and Buchinger, 2002).

Sun drying is the least expensive way to dry crops, but due of the previously listed drawbacks, the dried product's quality is much below expectations. By introducing appropriate drying technologies, such solar collector dryers, dried product quality can be improved and losses can be decreased.

Solar air collectors are largely designed to transform incident solar energy into usable heat within the drying chamber (Bunea et al., 2015). The utilization of solar energy has grown in popularity in recent years. A solar panel must be perpendicular to the radiation source in order to maximize the amount of energy it receives. Additionally, because the sun moves throughout the day and year, a solar panel must be able to track its movement in order to maximize power and increase energy harvesting.

The process of causing a solar collection surface to shift orientation in response to the sun's movement across the sky is known as solar tracking. While not necessary for a solar panel to function, the absence of a solar tracker can result in decreased performance in some applications.

Figure 1 shows the classification of solar tracker system, while Figure 2 shows components of solar tracking systems.

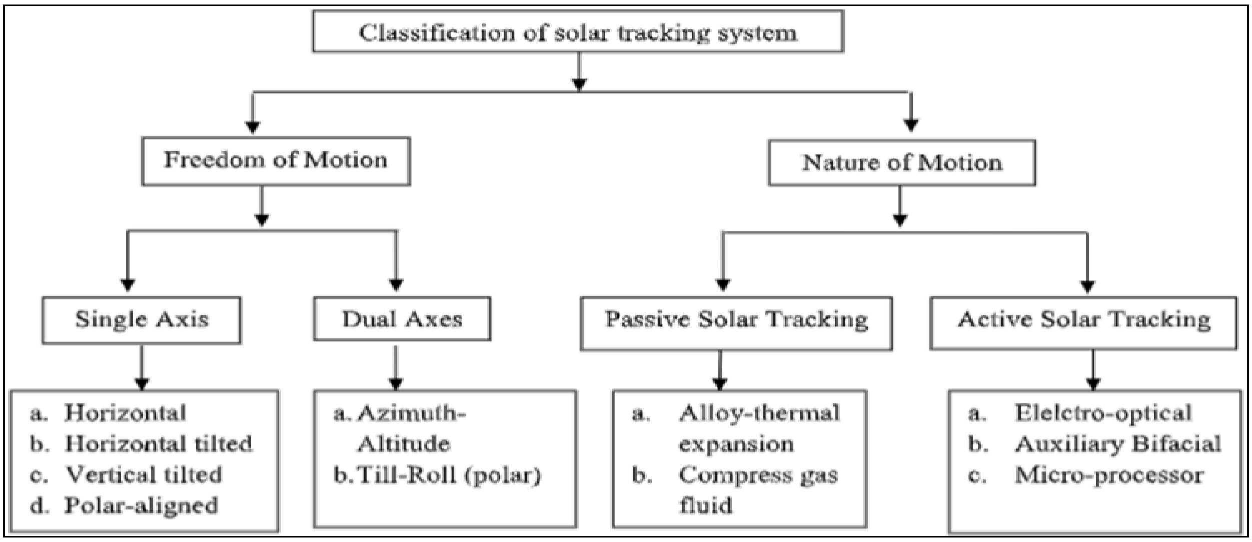

Fig 1 The Classification of Solar Tracker System (Source: Jamilu *et al*., 2019)

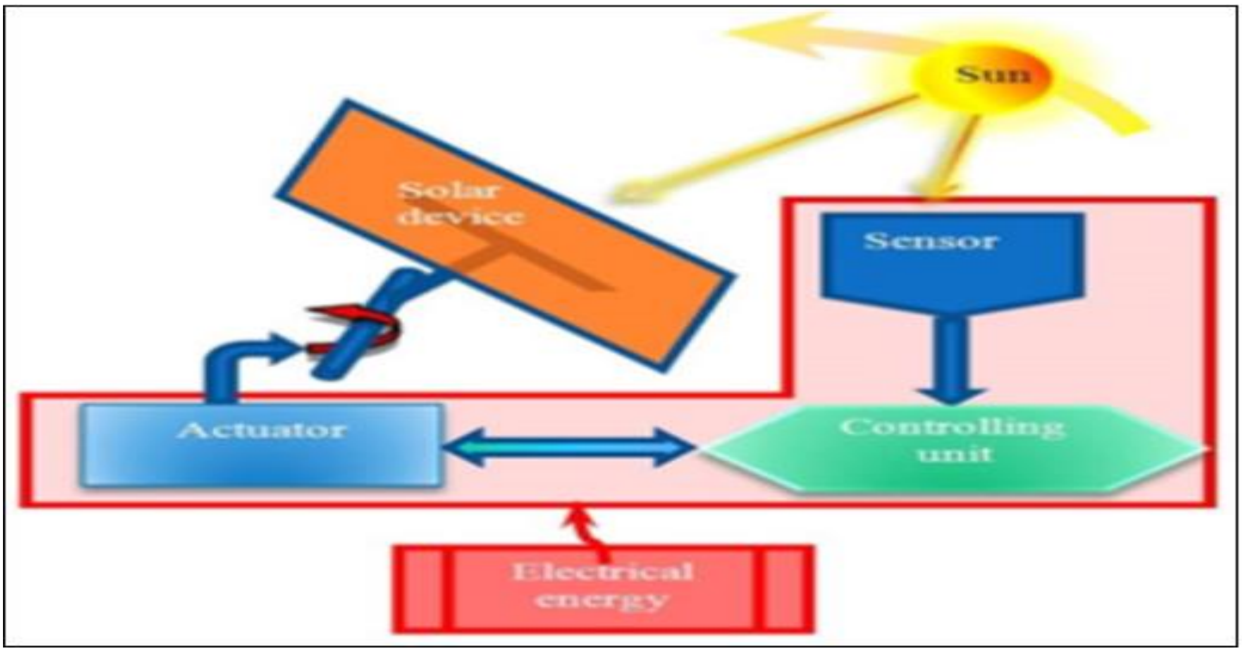

Fig 2 Working Elements of a Typical Sun Tracking System (Source: Sharma *et al*., 2016)

- *Drying of Okra and Pepper*

Due to its affordable and nutritious qualities, okra, often known as "lady finger" (*Abelmoschus esculentus*; see Figure 3) is regarded as a significant vegetable crop in most of the world. One of the most common vegetable crops grown in tropical and warmer regions of temperate countries is this one. According to Afolabi and Agarry (2014), the top 10 producers are Saudi Arabia, Nigeria, Iraq, Côte d'Ivoire, Pakistan, Egypt, Benin, Cameroon, and Ghana. Protein, iron, calcium, vitamins C and A, dietary fiber, and low saturated fat can all be found in okra (Doymaz, 2005). The essential and non-essential amino acids found in okra are similar to those found in soybeans. As a result, it is essential to human nutrition (Ononogbu, 1998).

According to Shivhare *et al.* (2000), fresh okra has an extremely high moisture content (88–90% wet basis), with 10% being the safe moisture content for storage. Soon after harvest, okra begins to deteriorate, resulting in significant post-harvest losses that seriously jeopardize food security (Sam, 1999). Research has also demonstrated that several tropical and subtropical crops, like okra, should not be stored at low temperatures because they are susceptible to rotting and discoloration from chilling damage.

The commodities are maintained using various procedures to meet the demand throughout the year in all locations; nevertheless, their processing may result in the loss of some of the features that once made them appealing to consumers.

Red pepper (*Capsicum annum* L.) is a spicy spice that is typically eaten as a condiment in the form of finely chopped flake or dried powder. The majority of peppers grown in Nigeria are utilized in regional cuisine, particularly stews. *Capsicum annum* var. Rodo, *Capsicum annum* var. Tatashe, *Capsicum frutescens* var. Bawa, and *Capsicum frutescens* var. Shombo (this variety is illustrated in Figure 4) are some of the common pepper cultivars in Nigeria. Peppers are commonly dried to; produce spices, extend its shelf life, stabilize the freshness of the product, reduce storage requirements, and lower transportation expenses.

The color of dried red peppers is a crucial quality indicator. They are much influenced by the temperature, moisture content, and drying duration during the drying process. Thus, understanding the drying kinetics, which reflect the temperature, moisture content, time history of red peppers, is crucial for designing a drying process that minimizes any degradation in the final product's quality.

Fig 3 Okra (Abelmoschus *esculentus*)

Fig 4 Pepper (Capsicum *frutescens* var. Shombo)

II. MATERIALS AND METHODS

- *Description of the Dryer*

The solar collector was constructed using wood coating to ensure minimal heat losses. The collector compartment was made up of an absorber plate and, an air inlet vent to conduct air into the collector compartment. The absorber plate was made of aluminum sheet painted black for maximum absorption of solar heat energy. The sides of the collector were fitted with Styrofoam to ensure the minimum loss of heat energy as it serves as insulation. The collector is to be connected to the solar drying chamber by means of a tube with a fan. The drying Chamber was made also of wood and it comprises of the three chambers-trays each made of wire mesh from galvanized iron sheets and a chimney. The structural support of the whole drying assembly was made from galvanized iron rods which can withstand adverse or unfavorable weather conditions.

- *Measurement (Instrumentation) and Design Procedure*

The design of the solar air collector for products drying processes is keeping many design parameters and standards in mind. Among these design parameters are;

- Relative humidity: Determined using humidity meter.
- Temperature: Determined using thermometer and temperature meters.
- Moisture content: Digital weighing balance was used to measure the weight of the agricultural products (okra and pepper) and Moisture content in dry basis (M.C. db) is given as:

$$\text{MC (d.b.) g water / g dry solids} = \frac{(w - d)}{\text{d}}$$

Where: w = weight of wet material, and d = weight of dry material

- Drying temperature: Average drying temperature, Td, of 45 ^{0}C was used.
- Amount of moisture to be removed: The formula to calculate the total amount of moisture to be removed (Mw) is given by Shivhare *et al.*, (2000) as:

$$M_w = \frac{W_w(M_i - M_f)}{(1 - M_f)} \quad (27)$$

Where: Mw = amount of moisture removed, Ww = initial total weight, M_i = initial moisture content on dry basis; M_f = the final moisture content on dry basis;

- Dryer Efficiency: Dryer efficiency which is the ratio of the energy needed to evaporate moisture from the material to the heat supplied to the dryer was calculated using (Dhanushkodi *et al.*, 2014):
-

$$\eta = \frac{W_w L}{I_c A_c t} \text{x } 100$$

$$= \frac{2.322 \ x \ 0.619}{0.773x \ 0.570x \ 12.00} \text{ x } 100 = 28.67\%$$

Where: W_w = Weight of moisture evaporated, Kg; L = Latent heat of evaporation of water at temperature of dryer, KJ/Kg; I_c = Solar radiation, kW/m^2; A_c = Area of collector, m^2; and t = Drying time

- Drying rate: Drying rate (D.R.) which is the amount of evaporated moisture over time (Dhanushkodi *et al.*, 2014) was calculated as follows:

$$\text{D.R} = \frac{M_i - M_d}{t}$$

Where: M_i = mass sample before drying; M_d = mass of sample after drying; and t = drying time.

- Collector orientation and angle: Solar air collectors are positioned to receive maximum sunlight, performing best when aligned perpendicular to the solar radiation. The ideal angle depends on the season, typically matching the site's latitude. In this case, a collector angle of 150^0 was used, and a solar tracker tilted the collector at an angle of 30^0 every 120 minutes. This was to prevent rainwater buildup during wet periods.
- Collector efficiency: Solar collector's efficiency is defined as the ratio of heat received by the drying air to the insulation upon the absorber surface.

Collector's efficiency was calculated using the following equation (Leon *et al.*, 2002).

$$\eta_c = \frac{V_a \times \rho \times \Delta T \times C_p}{A_c \times I_c}$$

$$= \frac{0.0217 \times 0{,}12 \times 293.15 \times 1840}{0.57x \ 773} = 25.24\%$$

Where: η_c = Collector's efficiency; V_a = Volumetric flow rate of air (m^3/s); ρ = Density of air (kg/m^3); ΔT = Temperature elevation (K); C_p = Specific heat capacity of air (J / kg.K); A_c = Area of solar collector (m^2); and I_c = Solar insolation on collector surface (W/m^2).

- Thermal efficiency: Thermal efficiency for the collector as given by Ekoja (2019);

$$\eta = \frac{(\rho_d A_d V_d)\, C_p\, (T_o - T_{amb})}{\alpha_a \tau I A p} \times 100$$

$$= \frac{(1.2 \text{ x } 0.004246 \text{ x } 0.0217 \text{ x } 184 \text{ x } 299)}{0.8 \text{ x } 0.7 \text{ x } 0.72 \text{ x } 304} \times 100$$

$$= 49.6\%$$

Where: ρ_d = Density of air at dryer inlet (or collector outlet) of the Collector; A_d = Area of cross section of dryer inlet of the collector; V_d = Velocity of air at dryer inlet of the collector; C_p = Specific heat capacity of air at dryer inlet; T_o = Collector outlet temperature (dryer inlet temperature) of the collector; T_{amb} = Ambient air temperature; α_a= Absorptivity of collector; τ = Solar Transmittance of glass; I = Solar radiation (w/m²); and A_p = Absorber plate area;

➢ *Experimental Design*

The measurements were repeated four times with four different sizes. Collected data were subjected to a completely randomized block design (CRBD). Mean values were further analyzed using analysis of variance (ANOVA) in split-plot factorial design involving CRBD.

➢ *Experimental Analysis*

The values of the coefficient of determination (R^2), and root mean square error (RMSE) were used to determine the quality of the drying model. The highest R^2 values and the lowest RMSE were selected to estimate which drying curve is the best (Ibrahim *et al.*, 2009).

➢ *Experimental Procedure and Evaluation*

The weight of the material to be dried, temperature, humidity, and sun insolation were among the characteristics examined during the solar dryer evaluation. Temperature meters and Thermo-hygrometers were used to measure the ambient temperature, the temperature and humidity inside the dryer and collector, and both. A solar power meter was used to measure the solar insulation. Before placing the product in the dryer, its original weight was determined using a weighing balance scale. Produce was removed from the dryer every two hours to check moisture content or weight loss once the drying process began.

Loaded test of the solar dryer was carried out using fresh okra and pepper. Okra and pepper samples of four sizes (5mm, 7mm, 10mm and 12mm) were used to carry out the drying process. The slices, above 100 grams for each treatment were weighed and distributed uniformly in three layers in the sample trays, and then dried in hot air dryer. A 12 volt battery was used to power the tracking system, the electrical circuit comprising the LDR, servo motor, resistor and battery was connected to the power output of the wiper motor. The circuit moves the collector box to the direction of the sun as the LDR moves with the intensity of the sunlight. The hot air drying was carried out by drying the samples at average air temperature of 40^{0}C and a constant air velocity of 1 m/s. The weighed slices were kept in steel plates to complete the drying process. Sample moisture losses were tracked every two hours. Okra and pepper samples were removed from the dryer and weighed at different times during the experiment to get the moisture loss of the drying samples. The samples' moisture loss was

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calculated using a digital electronic balance with a 0.01 g precision. The weight of water contained in a specific weight of dry solids was calculated as the moisture content using a dry basis (Mercer, 2014). In order to get more precise results, the trials were repeated. The average values were then used. Until no more weight loss was noted, the drying process was maintained. Every two hours, data on solar radiation, the surrounding temperature and humidity, the temperature of the drier, and the temperature of the collector output were recorded.

III. RESULTS AND DISCUSSION

The monitored data from the tracking collector are illustrated in Figures 5 – 12.

Plate 1 depicted an indigenously made solar tracking collector with peculiarities as: 200 watts motor wiper that can attain 150-degree rotation in a full wipe. Equipped with a sensor that is calibrated to allow a track of 30 degrees in 120 minutes according to Khavrus and Shelevytsky (2010), in that way, optimum and down times meant for drying crops - okra and pepper vegetables were appropriately captured.

The drying curves produced during the drying process (as shown in the Figures below) followed definite pattern irrespective of the trays in the drying chamber a similar value was reported by Timruwork (2015). With the polynomial behaviour, their equations were estimated with high correlation coefficient (R^2) ranging from 92 to 98%, a measure of theoretical correctness. In all, these 2nd order equation models of these curves, described the behaviour of the drying process.

The psychometric characteristics of the air for the drying process during No-Load Test showed temperature at average of 37℃, average ambient humidity of 25.75%, average collector temperature of 61℃, average solar radiation of 773W/m^2 spanning an insolation hour of 9 and sometimes 12 hours.

Plate 1 Pictorial View of the Dryer

Table 1 Sample Analysis of Moisture Content of Okra Slice (5mm)

Hour	Ambient Temp. °C	Ambient Humidity %	Chimney humidity %	Dryer Temp. °C			Weight of Sample, g			Dry Basis Moisture ($g H_2O/g$ solids)			Solar Radiation W/m^2	Dryer Humidity %		
				Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)		Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)
							Day 1									
10:00	25	26	30	26	40.5	40.6	42.5	42.5	42.5	7.5	7.5	7.5	799.1	28	28	29
12:00	23	22	27	21	43.4	44.6	26.9	26.5	27.1	4.38	4.3	4.42	849.1	23	24	25
14:00	20	19	25	20	43.2	44.3	25.1	20.3	24.2	4.02	3.06	3.84	901.3	20	21	22
16:00	29	30	35	30	39.7	40.9	23.1	19.9	21.3	3.62	2.98	3.26	511.4	32	33	33
							Day 2									
10:00	18	17	20	17	36.6	37.5	11	10.8	11	1.2	1.16	1.2	924.3	19	19	20
12:00	20	19	23	20	43	43.5	9	9.2	9	0.8	0.84	0.8	913	21	21	22
14:00	30	31	34	31	46.6	47.5	7.2	7.4	7.3	0.44	0.48	0.46	892	32	33	33
16:00	25	26	31	26	44.4	45.4	6.4	6.5	6.7	0.28	0.3	0.34	547.2	28	28	29
							Day 3									
10:00	20	19	23	20	38.6	38.5	5.8	5.9	5.6	0.16	0.18	0.12	757.7	21	21	22
12:00	29	30	30	30	41	41.3	5.6	5.7	5.5	0.12	0.14	0.1	830.7	29	29	29
14:00	26	25	26	24	47.6	48	5.6	5.6	5.5	0.12	0.12	0.1	935.8	25	25	26
16:00	18	17	18	17	45.7	45.8	5.6	5.6	5.5	0.12	0.12	0.1	655.9	17	17	17
							Day 4									
10:00	30	31	32	31	39.6	39.4	5.6	5.6	5.5	0.12	0.12	0.1	798.9	31	31	32
12:00	25	26	26	26	43.4	43.5	5.6	5.6	5.5	0.12	0.12	0.1	916.4	25	25	26
14:00	23	22	21	21	48.2	48.3	5.6	5.6	5.5	0.12	0.12	0.1	926.9	21	21	21
16:00	20	19	19	20	44	44.2	5.6	5.6	5.5	0.12	0.12	0.1	899.1	19	19	19

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Table 2 Sample Analysis of Moisture Content of Okra Slice (7mm)

Hour	Ambient Temp. ^0C	Ambient Humidity %	Chimney humidity %	Dryer Temp. ^0C			Weight of Sample, g			Dry Basis Moisture ($g\ H_2O/g$ solids)			Solar Radiation W/m²	Dryer Humidity %		
				Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 1 (bottom)	Tray 1 (bottom)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)		Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)
Day 1																
10:00	29.8	15	21	33.6	34.0	34.1	75.6	75.6	75.6	6.20	6.20	6.20	641.2	19	19	20
12:00	37.5	1	4	42.4	43.0	42.6	60.2	56.2	60.3	4.73	4.35	4.74	857.6	1	1	1
14:00	40.0	1	5	44.1	44.5	44.3	56.4	49.6	55.6	4.37	3.72	4.30	901.1	1	1	1
16:00	38.6	1	3	43.7	44.2	43.8	50.1	47.7	50.2	3.77	3.54	3.78	628.0	1	1	1
Day 2																
10:00	32.0	3	4	36.6	36.8	36.8	38.3	38.0	38.2	2.65	2.62	2.64	669.5	2	2	3
12:00	39.0	1	4	40.2	40.2	40.7	30.3	30.2	30.2	1.89	1.88	1.88	809.1	1	1	1
14:00	40.2	1	3	42.7	42.9	43.4	27.6	27.8	27.7	1.63	1.65	1.64	821.6	1	1	1
16:00	37.1	1	2	40.9	40.7	40.9	23.5	23.5	23.5	1.24	1.24	1.24	520.1	1	1	1
Day 3																
10:00	30.0	14	17	34.1	35.0	35.2	15.4	15.5	15.5	0.47	0.48	0.48	721.1	15	15	16
12:00	36.0	1	2	40.3	41.4	41.7	12.1	12.2	12.0	0.15	0.16	0.14	808.7	1	1	1
14:00	40	1	1	42.2	42.9	43.0	11.8	11.9	11.6	0.12	0.13	0.10	879.6	1	1	1
16:00	35	1	1	37.9	37.8	37.8	11.7	11.7	11.3	0.11	0.11	0.08	671.3	1	1	1
Day 4																
10:00	30	14	17	34.1	35.0	35.2	11.7	11.7	11.3	0.11	0.11	0.08	721.1	15	15	16
12:00	36	1	1	40.3	41.4	41.7	11.7	11.7	11.3	0.11	0.11	0.08	798.7	1	1	1
14:00	40	1	1	42.2	42.9	43.0	11.7	11.7	11.3	0.11	0.11	0.08	867.7	1	1	1
16:00	35	1	1	37.9	37.8	37.8	11.7	11.7	11.3	0.11	0.11	0.08	656.5	1	1	1

Table 3 Sample Analysis of Moisture Content of Okra Slice (10mm)

Hour	Ambient Temp. ^0C	Ambient Humidity %	Chimney humidity %	Dryer Temp. ^0C			Weight of Sample, g			Dry Basis Moisture ($g\ H_2O/g$ solids)			Solar Radiation W/m²	Dryer Humidity %		
				Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)		Tray 1 (bottom)	Tray 2 (midle)	Tray 3 (top)
Day 1																
10:00	35	32	35	36.7	38.8	41.1	99.7	99.7	99.7	8.32	8.32	8.32	711.7	33	33	34
12:00	40	13	18	41.1	41.8	42.1	85.7	84.8	82.8	7.01	6.93	6.74	932.2	15	15	16
14:00	37	18	24	41.6	42.6	43.8	71.7	72.5	67.2	5.70	5.78	5.28	883.2	20	21	22
16:00	35	17	23	40.5	40.9	40.9	57.4	59.6	56.6	4.36	4.57	4.29	743.1	19	20	21
Day 2																
10:00	31.2	31	34	38.1	38.2	38.9	40.4	40.4	37.7	2.78	2.78	2.52	626.9	32	32	33
12:00	40.0	27	31	41.6	43.0	43.0	33.7	33.3	31.6	2.15	2.11	1.95	915.2	28	28	29
14:00	41.0	22	25	46.0	46.4	46.5	29.2	29.9	28.0	1.73	1.79	1.62	922.3	23	23	24
16:00	36.0	20	26	40.1	40.5	40.3	25.1	25.7	23.8	1.35	1.40	1.22	813.0	21	22	23
Day 3																
10:00	35	28	31	36.5	37.0	38.0	18.8	19.0	17.8	0.76	0.76	0.66	862.9	29	29	30
12:00	43	17	22	43.0	44.9	44.9	17.2	17.6	16.1	0.61	0.64	0.50	920.9	19	19	20
14:00	45	11	15	46.0	46.3	47.0	14.6	14.7	13.9	0.36	0.37	0.30	913.1	12	12	13
16:00	39	10	14	40.8	41.0	42.1	13.8	13.9	13.1	0.30	0.30	0.22	798.2	12	12	13
Day 4																
10:00	35.7	45	46	35.8	36.6	37.1	13.2	13.4	12..7	0.23	0.25	0.19	494.3	43	43	44
12:00	33	39	42	40.7	40.6	41.0	12.5	12.7	12.2	0.17	0.19	0.14	822.1	40	40	41
14:00	44	15	19	43.5	46.1	47.1	11.8	11.9	11.8	0.10	0.11	0.10	900.4	16	16	17
16:00	36	11	15	39.8	38.6	37.1	11.8	11.9	11.8	0.10	0.11	0.10	731.1	12	12	13

Table 4 Sample Analysis of Moisture Content of Okra Slice (12mm)

Hour	Ambient Temp. ^0C	Ambient Humidity %	Chimney humidity	Dryer Temp. ^0C			Weight of Sample, g			Dry Basis Moisture ($g\ H_2O/g$ solids)			Solar Radiation W/m²	Dryer humidity %		
				Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)		Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)
Day 1																
10:00	28	14	17	32.4	32.6	32.9	80.2	80.2	80.2	5.97	5.97	5.97	640.0	15	15	16
12:00	36	1	2	41.5	42.0	42.1	63.2	64.1	62.4	4.50	4.57	4.43	867.1	1	1	1
14:00	40	1	2	43.4	44.0	44.2	49.3	49.8	48.1	3.29	3.33	3.18	901.4	1	1	1
16:00	37	1	2	42.0	42.3	42.4	32.0	32.2	32.8	2.69	1.78	1.80	628.4	1	1	1
Day 2																
10:00	30	11	16	34.8	35.1	35.3	20.4	20.4	20.3	0.77	0.77	0.77	589.7	12	13	14
12:00	35	1	3	40.7	41.6	41.8	19.9	20.0	19.7	0.73	0.74	0.71	731.3	1	1	1
14:00	39	1	2	43.4	44.5	44.7	16.9	16.9	16.7	0.47	0.47	0.45	841.3	1	1	1
16:00	34	1	1	29.8	40.2	40.2	14.8	14.3	14.1	0.29	0.24	0.23	703.7	1	1	1
Day 3																
10:00	30	12	17	33.0	33.2	34.4	14.5	14.2	14.0	0.26	0.23	0.22	746.8	14	14	15
12:00	31	1	2	38.3	39.5	41.2	14.4	14.1	13.9	0.25	0.23	0.21	670.2	1	1	1
14:00	39	1	1	41.1	41.4	41.6	14.2	14.0	13.8	0.23	0.23	0.20	738.3	1	1	1
16:00	38	1	1	37.1	41.6	37.6	13.9	13.9	13.6	0.21	0.21	0.18	501.1	1	1	1
Day 4																
10:00	28	12	16	32.9	31.7	33.1	12.8	12.7	12.5	0.11	0.10	0.09	746.8	14	14	15
12:00	32	1	1	38.8	39.0	41.1	12.3	12.2	12.1	0.07	0.06	0.05	810.2	1	1	1
14:00	39	1	1	42.1	42.0	42.7	12.3	12.2	12.1	0.07	0.06	0.05	838.3	1	1	1
16:00	31	1	1	35.0	38.3	37.4	12.3	12.2	12.1	0.07	0.06	0.05	581.1	1	1	1

Table 5 Sample Analysis of Moisture Content of Pepper Slice (5mm)

Hour	Ambient Temp. ^0C	Ambient Humidity %	Chimney humidity %	Dryer Temp. ^0C			Weight of Sample, g			Dry Basis Moisture ($g\ H_2O/g$ solids)			Solar Radiation W/m^2	Dryer Humidity %		
				Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)		Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)
Day 1																
10:00	34	3	8	39.6	39.8	39.6	46	46	46	5.13	5.13	5.13	695.8	5	5	6
12:00	40	1	4	42.2	42.2	42.6	23.8	25	24.0	2.17	2.33	2.20	829.9	1	1	1
14:00	39	1	4	42.7	43.4	43.7	15.3	14.4	14.9	1.04	0.92	1.00	707.1	1	1	1
16:00	37	1	3	40.9	40.7	40.8	10.8	10.6	10.1	0.44	0.41	0.35	520.3	1	1	1
Day 2																
10:00	29	3	6	34.9	35.3	35.3	8.1	8.2	8.0	0.08	0.09	0.07	717.5	4	4	5
12:00	36.6	1	2	40.2	41.8	41.8	7.8	7.9	7.9	0.04	0.05	0.05	811.6	1	1	1
14:00	39.3	1	1	43.3	44.0	44.0	7.7	7.8	7.8	0.03	0.04	0.04	824.1	1	1	1
16:00	35.7	1	1	39.8	40.0	40.1	7.7	7.7	7.8	0.03	0.03	0.04	380.0	1	1	1
Day 3																
10:00	29	5	9	33.6	34.0	34.1	7.6	7.7	7.7	0.01	0.03	0.03	641.2	7	7	8
12:00	37	1	1	42.4	43.0	42.6	7.6	7.7	7.7	0.01	0.03	0.03	857.6	1	1	1
14:00	39	1	1	44.7	45.1	44.9	7.6	7.7	7.7	0.01	0.03	0.03	889.2	1	1	1
16:00	38	1	1	43.7	44.2	43.8	7.6	7.7	7.7	0.01	0.03	0.03	628.0			

Table 6 Sample Analysis of Moisture Content of Pepper Slice (7mm)

Hour	Ambient Temp. ^0C	Ambient Humidity %	Chimney humidity %	Dryer Temp. ^0C			Weight of Sample, g			Dry Basis Moisture ($g\ H_2O/g$ solids)			Solar Radiation W/m^2	Dryer Humidity %		
				Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)		Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)
Day 1																
10:00	30	13	19	32.2	33.1	33.2	56.3	56.3	56.3	5.12	5.12	5.12	740.8	15	15	16
12:00	31	1	6	40.0	39.4	41.3	34.1	36.3	33.0	2.71	2.95	2.59	670.1	1	1	1
14:00	39	1	5	41.1	41.3	41.8	25.3	28.4	24.7	1.75	2.09	1.68	730.1	1	1	1
16:00	37	1	5	39.2	39.8	39.6	16.9	19.1	17.2	0.84	1.08	0.87	498.6	1	1	1
Day 2																
10:00	33	5	8	38.1	33.1	33.2	12.3	13.5	13.2	0.34	0.47	0.43	701.9	6	6	7
12:00	37	1	4	40.1	39.4	41.3	10.9	11.7	10.8	0.18	0.27	0.17	781.4	1	1	1
14:00	41	1	3	41.1	41.3	41.9	10.6	10.9	10.7	0.15	0.18	0.16	899.9	1	1	1
16:00	35	1	3	39.2	39.8	39.6	9.8	10.2	10.0	0.07	0.11	0.09	711.8	1	1	1
Day 3																
10:00	29	16	20	33.2	33.5	33.5	9.6	10.0	9.6	0.04	0.09	0.04	760.1	17	17	18
12:00	38	1	2	40.2	41.1	41.9	9.4	9.8	9.4	0.02	0.07	0.02	800.3	1	1	1
14:00	42	1	2	44.5	44.9	45.0	9.4	9.6	9.4	0.02	0.04	0.02	901.1	1	1	1
16:00	32	1	1	39.7	40.2	40.5	9.4	9.6	9.4	0.02	0.04	0.02	756.1	1	1	1

Table 7 Sample Analysis of Moisture Content of Pepper Slice (10mm)

Hour	Ambient Temp. ^0C	Ambient Humidity, %	Chimney humidity %	Dryer Temp. ^0C			Weight of Sample, g			Dry Basis Moisture ($g\ H_2O/g$ solids)			Solar Radiation, W/m^2	Dryer humidity %		
				Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)		Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)
Day 1																
10:00	37	13	19	39.4	39.8	39.8	64.1	64.1	64.1	4.39	4.39	4.39	787.6	15	15	16
12:00	40	2	7	43	44.1	44.1	52.4	55	51.6	3.4	3.62	3.34	943.6	3	3	4
14:00	43	1	4	45.8	46.1	46	42.8	47.4	43.4	2.6	2.98	2.65	912.6	1	1	1
16:00	45	1	3	42.2	42.5	43	34.1	39.1	36.2	1.87	2.29	2.04	738.1	1	1	1
Day 2																
10:00	32	20	26	36.3	36.3	37.1	24.2	29	26.5	1.03	1.44	1.23	882.7	22	22	23
12:00	39	16	22	41.2	41.4	42	22.2	26.9	23.4	0.87	1.26	1	928.1	17	18	19
14:00	40	3	7	43.2	43.3	44	21	25	22	0.76	1.1	0.85	931.2	4	4	5
16:00	34	1	4	40	40.1	40.1	20.1	23.6	20.7	0.69	0.98	0.74	455.3	1	1	1
Day 3																
10:00	30	26	30	33.2	33.3	34.5	19	21	18.7	0.6	0.76	0.57	746.8	27	27	28
12:00	31	20	24	38.3	39.4	41.3	18.6	20.5	18.3	0.56	0.72	0.54	672.1	22	22	23
14:00	39	4	9	41.1	41.3	41.3	18	19.7	17.7	0.51	0.75	0.49	728.1	5	6	7
16:00	38	4	9	39.5	39.8	39.6	17.5	19.3	17.4	0.47	0.62	0.46	494	6	6	7
Day 4																
10:00	30	3	6	33.2	33.4	33.9	14.9	15.1	14.7	0.25	0.27	0.24	647	4	4	5
12:00	32	1	6	41.5	41.8	42	13.4	13.8	13.4	0.13	0.16	0.13	711.8	1	1	1
14:00	34	1	5	43.2	43.3	44	13	13.4	12.9	0.09	0.13	0.08	823.3	1	1	1
16:00	29	2	5	40.1	39.8	40.3	12.5	12.4	12.4	0.05	0.04	0.04	691.4	3	3	3

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Table 8 Sample Analysis of Moisture Content of Pepper Slice (12mm)

Hour	Ambient Temp. ⁰C	Ambient Humidity, %	Chimney Humidity %	Dryer Temp. ⁰C			Weight of Sample, g			Dry Basis Moisture ($g\ H_2O/g$ solids)			Solar Radiation, W/m^2	Dryer Humidity %		
				Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)	Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)		Tray 1 (bottom)	Tray 2 (middle)	Tray 3 (top)
			Day 1													
10:00	35	9	13	39	40.1	40.1	70	70	70	4.98	4.98	4.98	721.6	11	11	12
12:00	39	1	4	42.9	43.2	43.4	58.3	59.2	57.3	3.98	4.06	3.9	921.3	1	1	1
14:00	41	1	3	45.6	46.1	46.1	48.7	49.7	48.6	3.16	3.25	3.15	941.4	1	1	1
16:00	37	1	3	42.1	42.1	42	40.1	42.4	41.3	2.43	2.62	2.53	728.2	1	1	1
			Day2													
10:00	34	8	13	38.6	39.2	39.2	30.6	32.8	30.9	1.62	1.8	1.64	699.6	10	10	11
12:00	49	1	3	42.5	42.8	42.9	28.7	30.1	29.2	1.45	1.57	1.5	813.4	1	1	1
14:00	42	1	3	43.9	44.2	44.7	27	28.4	26.9	1.31	1.43	1.3	889.1	1	1	1
16:00	37.8	1	2	40.8	41.1	41.2	25.4	26	25.4	1.17	1.22	1.17	721.8	1	1	1
			Day 3													
10:00	29	13	19	33.4	33.2	33.3	20.2	22.1	19.6	0.73	0.89	0.68	680.1	15	16	17
12:00	36	1	2	41.1	42.1	42.3	19.6	20.3	18.4	0.68	0.74	0.57	731.7			
14:00	38	1	2	43.4	44.5	45	17.9	18.3	17.5	0.53	0.56	0.5	811.4			
16:00	35	1	2	41.6	41.8	42	16.3	17.1	16.3	0.39	0.46	0.39	710.4			
			Day 4													
10:00	28	9	13	32.4	32.4	32.3	15	15.9	14.8	0.28	0.36	0.26	670.1	10	10	11
12:00	32	1	2	40.9	41.3	41.4	13.8	14.2	13.7	0.18	0.21	0.17	751.1	1	1	1
14:00	39	1	1	43.5	44.1	44.5	12.1	12.2	11.9	0.03	0.04	0.02	881.7	1	1	1
16:00	35	1	1	38.8	40.1	40.1	11.9	11.9	11.9	0.02	0.02	0.02	723.2	1	1	1

Table 9 Moisture Content of the Drying Okra and Pepper Slices Over Time

	Okra				Pepper			
Time, h	**Size 1**	**Size 2**	**Size 3**	**Size 4**	**Size 1**	**Size 2**	**Size 3**	**Size 4**
Optimum time, T_1	5.75	5.41	7.61	5.24	3.67	3.94	3.90	4.48
	1.08	2.26	2.45	0.75	0.07	0.32	1.12	1.58
	0.13	0.32	1.54	0.23	0.03	0.05	0.63	1.71
	0.12	0.1	0.69	0.08			0.20	0.23
Down time, T_2	3.55	3.99	5.03	2.55	0.70	1.34	2.39	2.85
	0.38	1.44	1.54	0.36	0.04	0.13	0.80	1.25
	0.12	0.11	0.33	0.22	0.03	0.03	0.54	0.46
	0.12	0.1	0.1	0.06			0.07	0.03

Table 10 ANOVA Analysing the Moisture Content of the Drying Okra Slices over Time

Source	**df**	**Ss**	**ms**	**F-cal**	**F-tab**	
					5%	1%
CFM	1	90.3168				
Blocks	3	115.6337	38.5446*	22.1343	9.28	29.5
Factor A	1	5.9168	5.9168^{ns}	3.3977	10.1	34.1
Error (a)	3	5.22415	1.7414			
Main plot	7	126.7747				
Factor B	3	6.83815	2.2794**	33.57	3.16	5.09
AB	3	3.7274	1.2425^{ns}	18.299	3.16	5.09
Error(b)	18	1.222	0.0679			
Total	31	138.5402				

ns = not significant @P≤5% and 1%; ** = highly significant @ P≤1%; * = significant@ P≤5%

Table 11 ANOVA Analysing the Moisture Content of the Drying Okra Slices over Time

Source	**Df**	**ss**	**ms**	**F-cal**	**F-tab**	
					5%	1%
CFM	1	42.82682				
Blocks	3	29.89811	9.9660^{ns}	6.2005	9.28	29.5
Factor A	1	4.986817	4.9868^{ns}	3.1026	10.1	34.1
Error (a)	3	4.822006	1.6073			
Main plot	7	39.70693				
Factor B	3	6.236683	2.0789^{ns}	1.1234	3.16	5.09
AB	3	0.16095	0.05365^{ns}	0.0289	3.16	5.09
Error(b)	18	33.3093	1.8505			
Total	31	47.47478				

ns = not significant @ all levels of probability

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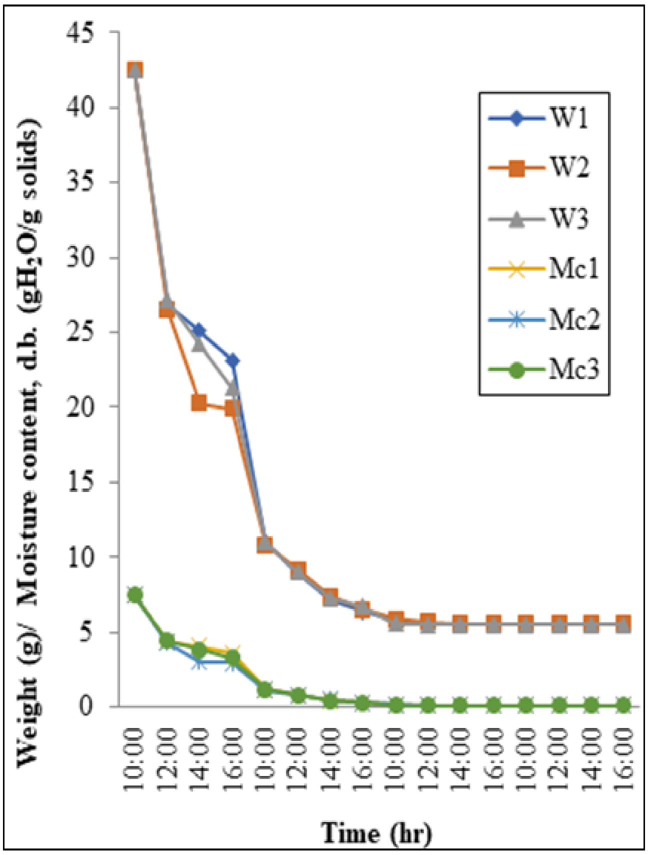

Fig 5 Sample Analysis of Moisture Content of Okra slice (5mm)

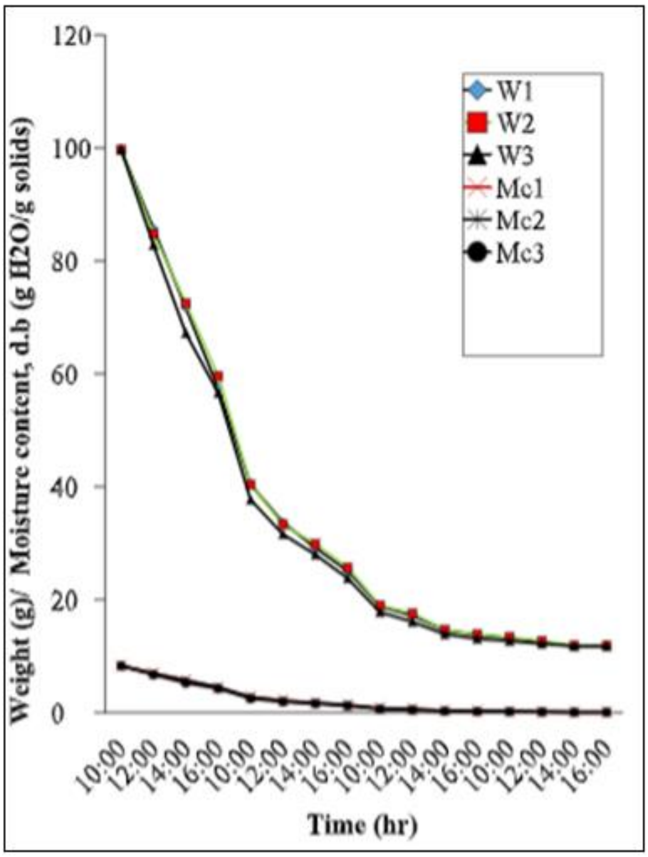

Fig 7 Sample Analysis of Moisture Content of Okra Slice (10mm)

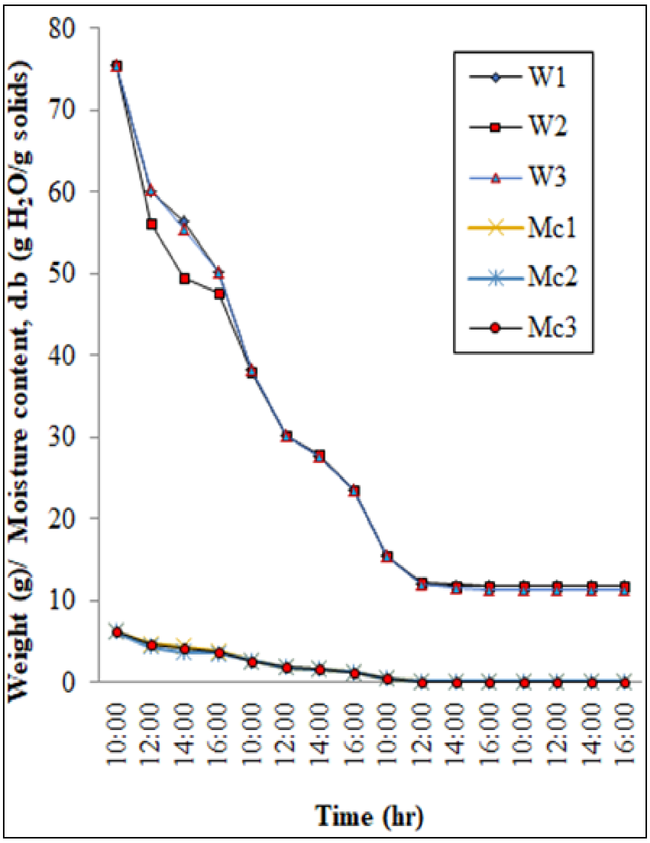

Fig 6 Sample Analysis of Moisture Content of Okra slice (7mm)

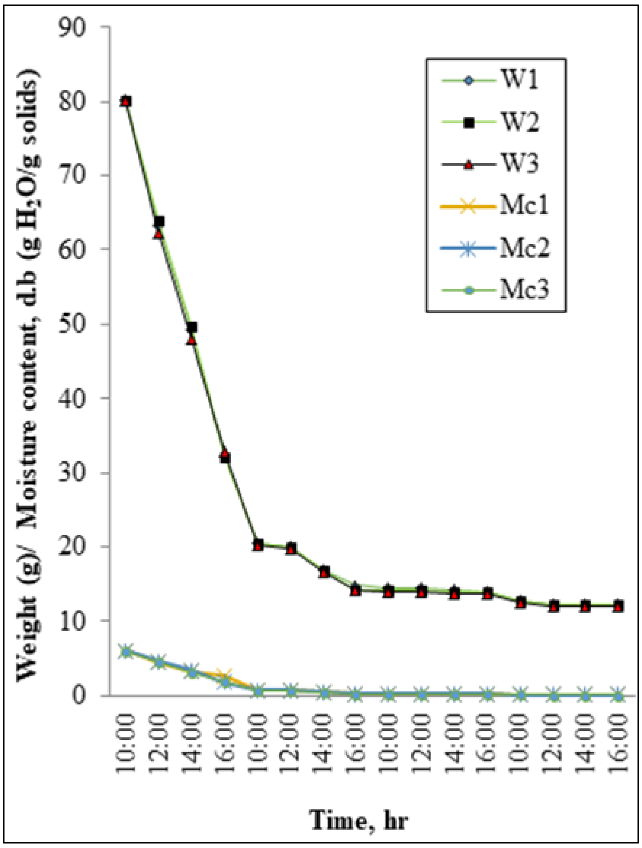

Fig 8 Sample Analysis of Moisture Content of Okra Slice (12mm)

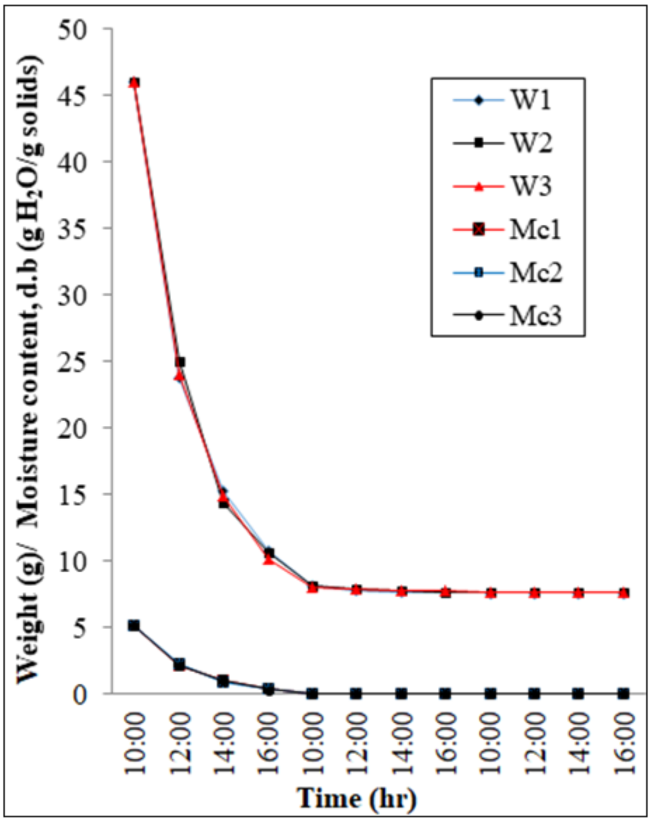

Fig 9 Sample Analysis of Moisture Content of Pepper Slice (5mm)

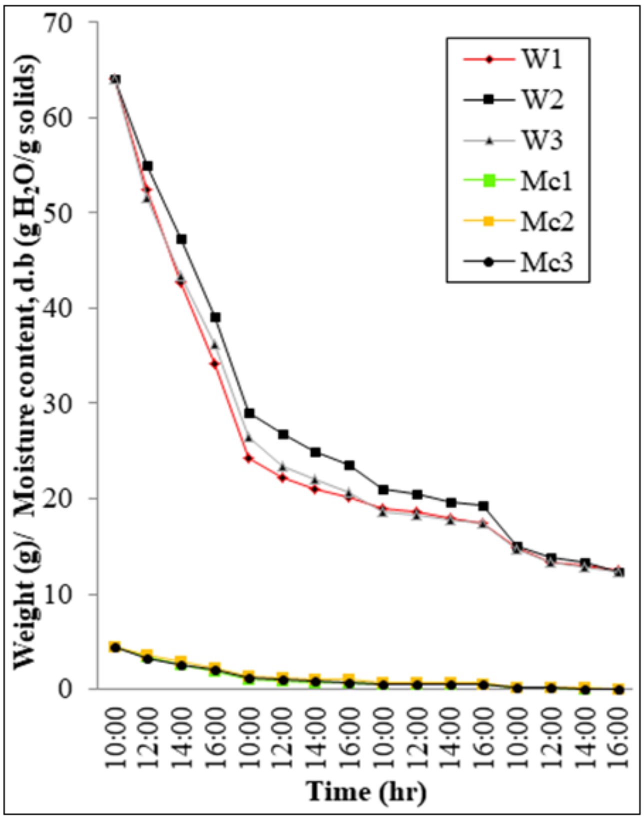

Fig 11 Sample Analysis of Moisture Content of Pepper Slice (10mm)

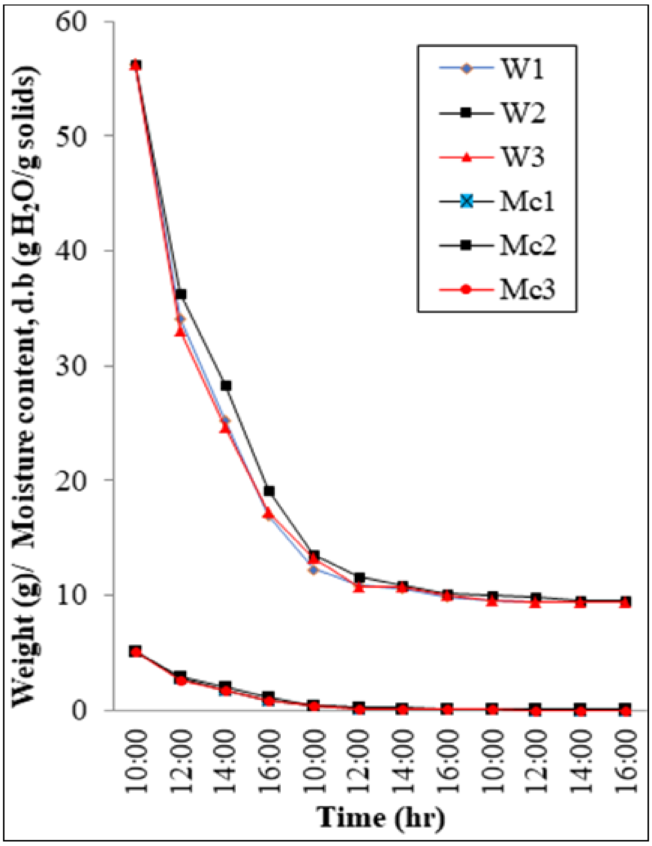

Fig 10 Sample Analysis of Moisture Content of Pepper Slice (7mm)

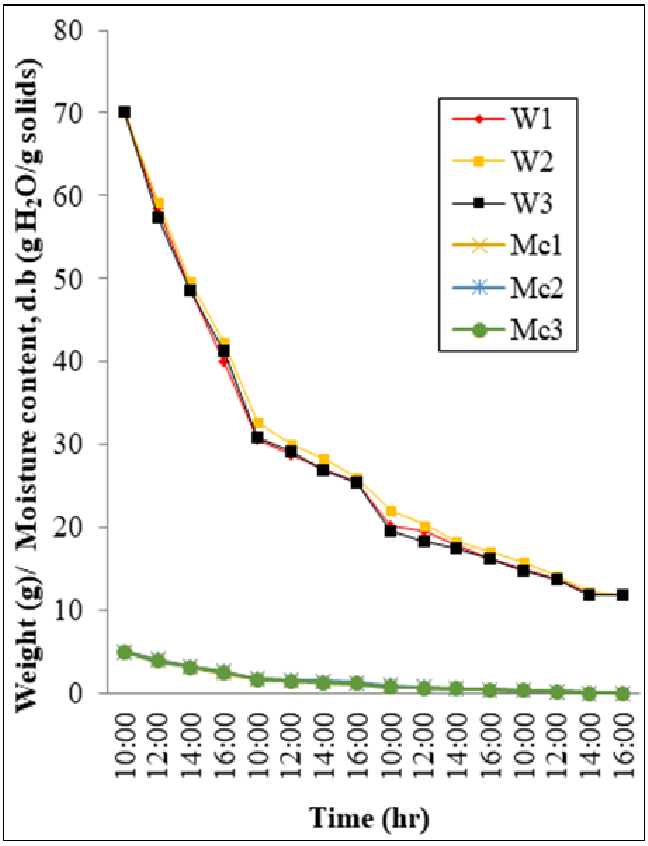

Fig 12 Sample Analysis of Moisture Content of Pepper Slice (12mm)

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- *Experimental Drying of Okra Slice @ 5mm Size*

From Table 1, 42.5 gm, 42.5 gm, 42.5 gm, were loaded onto tray1, tray2 and tray3 of the drying chamber and after an insolation time of 14 hours in 3 days, weights of 5.6gm, 5.6 gm and 5.5gm of the samples were recorded, accounting for 86.8%, 86.8%, and 87% weight reduction across the three trays. The drying curves in Figure 5 showed a polynomial behaviour of 2nd order equations represented as: $y = 0.3056x^2 - 7.0526x + 43.633$ for tray1 and correlation coefficient, $R^2 = 0.9293$; $y = 0.2952x^2 - 6.7477x + 41.521$ for tray2 ($R^2 = 0.9153$) and $y = 0.3042x^2 - 7.0041x + 43.167$ for tray3($R^2 = 0.933$).

- *Drying of Okra Slice @ 7mm Size*

From Table 2, 75.6 gm, 75.6 gm, 75.6 gm, were loaded onto tray1, tray2 and tray3 of the drying chamber respectively and after an insolation time of 12 hours in 4 days, and solar radiation of 748.3W/m^2, weights of 11.7 gm, 11.7 gm and 11.3 gm of the samples were recorded, accounting for 84.5%, 84.5%, and 85% weight reduction across the three trays. The drying curves in Figure 6 showed a polynomial behaviour of 2nd order equations represented as: $y = 0.4313x^2 - 11.391x + 85.231$ for tray1 and correlation coefficient, $R^2 = 0.991$; $y = 0.4054x^2 - 10.728x + 81.2$ for tray2 ($R^2 = 0.9846$) and $y = 0.4272x^2 - 11.343x + 85.032$ for tray3 ($R^2 = 0.9914$). One immediate observation is that with the increase in slice thickness, weight loss percentage reduced over the drying period, this in in agreement with Forson, et.al. (2007) findings.

- *Drying of Okra Slice @10mm Size*

From Table 3, 99.7gm, 99.7gm, 99.7gm, were loaded onto tray1, tray2 and tray3 of the drying chamber respectively and after an insolation time of 12 hours in 4 days, and average solar radiation of 748.3W/m^2, weights of11.8 gm, 11.9 gm and 11.8gm of the samples were recorded, accounting for 88.2%, 88.1%, and 88.2% weight reduction across the three trays. The drying curves in Figure 7 showed a polynomial behaviour of 2nd order equations represented as: $y = 0.634x^2 - 16.149x + 112.77$ for tray1 and correlation coefficient, $R^2 = 0.9865$; $y = 0.6269x^2 - 16.039x + 112.79$for tray2 ($R^2 = 0.9859$) and $y = 0.6448x^2 - 16.174x + 110.74$ for tray3 ($R^2 = 0.9835$). In this slice size, there is a significant weight reduction and higher values of correlation coefficient.

- *Drying of Okra Slice @12mm Size*

From Table 4, 80.2gm, 80.2gm, 80.2gm, were loaded onto tray1, tray2 and tray3 of the drying chamber respectively and after an insolation time of 12 hours in 4 days, and average solar radiation of 720.9W/m^2, weights of 12.3gm, 12.2gm and 12.1gm of the samples were recorded, accounting for 84.7%, 84.8%, and 84.9% weight reduction across the three trays. The drying curves from Figure 8 showed a polynomial behaviour of 2nd order equations represented as: $y = 0.5782x^2 - 13.272x + 83.971$ for tray1 and correlation coefficient, $R^2 = 0.9202$; $y = 0.5853x^2 - 13.432x + 84.66$for tray2 ($R^2 = 0.9224$) and $y = 0.5799x^2 - 13.298x + 83.713$ for tray3 ($R^2 = 0.9239$). In this slice size, there is also a weight reduction and higher values of correlation coefficient.

- *Experimental Drying of Pepper Slice @ 5mm Size*

As in the experimental drying of Okra in the preceding section, the psychometric characteristics of the air for the drying process of pepper slice are specified on Table 5. Initial weights of 46 gm, 46 gm, and 46gm were weighed onto the three trays of the drying chamber at the average solar radiation of 708.5 W/m^2. When drying was completed after an insolation time of 9 hours in 3 days, final weights recorded for the 3 trays were 7.6gm, 7.7gm and 7.7 gm respectively. This accounted for a weight reduction of 66.95 %, 66.52 % and 66.52 %. Figure 9, a polynomial behaviour of 2nd order equations represented were obtained a follow: $y = 0.61x^2 - 10.166x + 46.168$ with a correlation coefficient $R^2 = 0.8416$ for tray1; $y = 0.6172x^2 - 10.262x + 46.468$ for tray2 with $R^2 = 0.8406$, while tray3 has $y = 0.614x^2 - 10.188x + 46.075$ ($R^2 = 0.8333$).

- *Drying of Pepper Slice @7mm Size*

From Table 6, 56.3gm, 56.3gm and 56.3gm were loaded onto tray1, tray2 and tray3 of the drying chamber respectively and after an insolation time of 9 hours in 3 days, and average solar radiation of 746 W/m^2, weights of 9.4gm, 9.6gm, 9.4gm, of the samples were recorded, accounting for 83.3 %, 82.9 %, and 83.3 % weight reduction across the three trays. The drying curves in Figure 10 showed a polynomial behaviour of 2nd order equations represented as: $y = 0.61x^2 - 10.166x + 46.168$ for tray1 and correlation coefficient, $R^2 = 0.8416$; $y = 0.6172x^2 - 10.262x + 46.468$ for tray2 ($R^2 = 0.8406$) and $y = 0.614x^2 - 10.188x + 46.075$ for tray3 ($R^2 = 0.8333$).

- *Drying of Pepper Slice @10mm Size*

Initial weights of 64.1 gm, 64.1 gm, and 64.1 gm were weighed onto the three trays of the drying chamber (see Table 7) at the average solar radiation of 755.9 W/m^2. When drying was completed after an insolation time of 12 hours in 4 days, final weights recorded for the 3 trays were 12.5gm, 12.4gm, and 12.4gm respectively. This amounted to a weight reduction of 80.5 %, 80.7 % and 80.7 %. Figure 11, a polynomial behaviour of 2nd order equations represented as $y = 0.343x^2 - 8.5648x + 66.215$ with a correlation coefficient $R^2 = 0.933$for tray1; $y = 0.2934x^2 - 7.9606x + 68.067$ for tray2 with $R^2 = 0.9618$, while tray3 has $y = 0.3305x^2 - 8.4229x + 66.534$ ($R^2 = 0.9526$).

- *Drying of Pepper Slice @12mm Size*

From Table 8, 70.0 gm, 70 gm, 70 gm were loaded onto tray1, tray2 and tray3 of the drying chamber respectively and after an insolation time of 12 hours in 4 days, and average solar radiation of 774.8 W/m^2, weights of 11.9gm, 11.9gm, 11.9gm, of the samples were recorded, accounting for 66%, 66%, and 66% weight reduction across the three trays. The drying curves from Figure 12 showed a polynomial behaviour of 2nd order equations represented as: $y = 0.3306x^2 - 8.9482x + 73.626$ for tray1 and correlation coefficient, $R^2 = 0.9712$; $y = 0.3103x^2 - 8.6694x + 74.093$ for tray2 ($R^2 = 0.9782$) and $y = 0.3315x^2 - 8.982x + 73.712$ for tray3 ($R^2 = 0.9759$).For pepper drying at slice sizes of 5 mm and 7 mm, the correlation of coefficient values R^2 ranged from 0.833 to 0.994 while these values changed from 0.962 to 0.978 for slices of 10 mm and 12 mm. However, insolation drying time was more for slice sizes of 10 mm and 12 mm.

➢ *Mean Analysis of Optimum and Down Times*

Optimum and Down times of moisture removal were analyzed and compared. ANOVA was conducted and mean used for the effects of those times in drying down the moisture. Mean values of these parameters were considered for variations utilizing analysis of variance (ANOVA) in split-plot factorial design involving CRBD. Tables 10 and 11 are the ANOVA tables detailing the comparison between optimum time and the down time. While Table 10 represents ANOVA analyzing the moisture content of the drying okra slices over time, Table 11 showed ANOVA analyzing the moisture content of the drying pepper slices over time. The result on Table 11 showed Factor A (the 2 different times) not significant (ns)@$P \leq 5\%$ and 1%; while Factor B (4 slice sizes) was highly significant @ $P \leq 1\%$. However, mean analysis results on Table 11 indicate ns = not significant effects of the 2 factors considered @ all levels of probability but having the down time for Pepper appearing more significantly in removing moisture and attaining shorter drying time than the optimum times in the insolation period.

IV. CONCLUSION AND RECOMMENDATIONS

➢ *Conclusion*

Development of a solar collector for agricultural products drying that can be used for drying vegetables was designed, constructed and evaluated using materials readily available in the market. A solar tracking device was designed and developed to trace the sun's trajectory, ensuring the generation of the highest attainable power and increase the energy harvested and thereby optimizing the amount of energy received. A prototype of a tracker controlled solar collector/dryer was also designed and produced.

The dryer performance was evaluated using okra and pepper. In assessing the various conducted tests, the performance parameters considered for evaluation comprised temperature, moisture content of the produce, collector and drying efficiencies, drying period, and drying rate.

The moisture content of okra experienced a reduction from 87 % (w.b,), 7.0 g H_2O/g solids (d.b) to 13% (w.b), 0.1 g H_2O/g solids(d.b) respectively and the moisture content of pepper experienced a reduction from 83 % (w.b), 4.89 g H_2O/g solids(d.b) to 17 % (w.b), 0.03 g H_2O/g solids (d.b) respectively in a span of two to four days.

The drying rate for okra was identified to be 2.00 (g H_2O/g solids)/h whereas for pepper it was 0.67(g H_2O/g solids)/h, The collector efficiency was identified to be 25.24 % and drying efficiency was also identified to be 28.67%.

The drying curves, typical of thin layer type, produced during the drying process, followed definite pattern irrespective of the trays in the drying chamber. With the polynomial behaviour, their equations, typical of Okra was $y = 0.3056x^2 - 7.0526x + 43.633$ and R^2 were estimated highly with correlation coefficient (R^2) ranging from 91 to 99%, and for Pepper as: $y = 0.61x^2 - 10.166x + 46.168$ and R^2 values ranged from 83 – 94% - a measure of theoretical correctness. These high values of correlation coefficients obtained from the drying curves bore reasonable closeness between the experiment and theory. In all, these 2nd order equation models of these curves, described the behaviour of the drying process.

This work provided a good insight into what possibilities local technologies can do. The products of drying displayed showed good indices of acceptability, attainment of shelf-life moisture content, and showing aesthetic and commercial appeals.

➢ *Recommendations*

Building upon the outcomes of this study, the following recommendations are necessary;

- Research of this weather sensitivity can do better in periods of relative high insolation.
- More of wiper types and capacities could be explored.
- Funding can be a problem getting this prototype to the market.

REFERENCES

[1]. Afolabi, T. J., & Agarry, S. E. (2014). Thin layer drying kinetics and modelling of okra (Abelmoschus esculentus (L.) Moench) slices under natural and forced convective air drying. Food Science and Quality Management, 28(6), 35-49.

[2]. Ahmmad, B., Kitamura, Y., Kusumoto, Y., Yang, H. and Abdulla-Al-Mamun, M. (2010). A New Type of Solid State Solar Cell Based on Fe_2O_3, SiC and Crystal Growth Inhibitors. *Journal of Scientific Research*, **2**(1): 1 – 8.

[3]. Bahloul, N., Boudhrioua, N., Kouhila, M. and Kechaou, B. (2009) Effect of Convective Solar Drying on Colour, Total Phenols and Radical Scavenging Activity of Olive Leaves (*Olea europaea* L). *International Journal of Food Science & Technology,* **44**: 2561 – 2567.

[4]. Bechoff, A., Dufour, D., Dhuique-Mayer, C., Marouzé, C. and Reynes, M. (2009). Effect of Hot Air, Solar and Sun Drying Treatments on Provitamin a Retention in Orange- fleshed Sweet Potato. *Journal of Food Engineering*, **92**: 164 – 171.

[5]. Bunea, M., Perers, B., Eicher, S., Hikdbrand, C., Bony, J. and Citherlet S. (2015). Mathematical Modelling Of Unglazed Solar Collectors Under Extreme Operating Conditions. *Sol. Energy*, **118**: 547 – 561.

[6]. Dhanushkodi, S., Wilson, V.H. and Sudhakar, K. (2014). Thermal Performance Evaluation of Indirect Forced Cabinet Solar Dryer for Cashew Drying. *American-Eurasian Journal of Agricultural and Environmental Science*, **14**(11): 1248–1254.

ISSN No:-2456-2165

[7]. Doymaz, I. (2005). Drying Characteristics and Kinetics of Okra. *Journal of Food Engineering*, **69**, 275 – 279.
[8]. Eklou, A.S, Ines, M.S., Francis, N., Moussa, S., Ayoni, O.A., Kayode, S. and Danie, T.D. (2006). Comparative Studies of Drying Methods on the Seed Quality of Interspecific NERICA Rice Varieties (*Oryzaglaberrimax, Oryza sativa*) and their Parents. *African Journal of Biotechnology*, **5**: 1618 – 1624.
[9]. Ekoja, M. (2019). Experimental Study of a Glazed Transpired Solar Air Heater in Natural Convection Mode. Phd Thesis submitted to Department of Mechanical Engineering UNN, Enugu Nigeria.
[10]. Forson, F.K., Nazha, M.A.A., Akuffo, F.O. and Rajakaruna, H. (2007). Design of Mixed Model Natural Convection Solar Crop Dryers: Application of Principles and Rules of Thumb. *Journal of Renewable Energy*, **32**(14): 2306–2319.
[11]. Ibrahim, M., Sopian, K. and Daud, W.R.W (2009). Study of the Drying Kinetics of Lemon Grass. *American Journal of Applied Sciences* **6**(6): 1070-1075.
[12]. Irtwange, S.V. and Adebayo, S. (2009). Development and Performance of a Laboratory- scale Passive Solar Grain Dryer in a Tropical Environment, *Journal of Agricultural Extension and Rural Development*, **1**(2):42–49.
[13]. Jamilu, Y., Muhammad, M., Tajudeen, J., Ibrahim, B.K., Mohammed, A.G., Ibrahim, M. (2019). A Review on Solar Tracking System: A Technique of Solar Power Output Enhancement. *Engineering Science*, **4**(1): 1-11. doi: 10.11648/j.es. 20190401.11
[14]. Khavrus, V. and Shelevytsky, I. (2010). Introduction to Solar Motion Geometry on a Basis of a Simple Model. *Physics Education*, **45** (6): 641.
[15]. Leon, M.A., Kumar, S. and Bhattacharya, S. (2002). A Comprehensive Procedure for Performance Evaluation of Solar Food Dryers. *Renewable and Sustainable Energy Reviews*, **6**: 367 – 393.
[16]. Mercer, D.G. (2014). An Introduction to the Dehydration and Drying of Fruits and Vegetables. Department of Food Science, University of Guelph. Ontario, Canada. ISBN 978-0-88955, 621-8.
[17]. Ononogbu, I.C (1998). Lipids and Proteins: Chemistry Methodology Metabolism Biochemical and Physiological Importance. New Africa Publishing Co. Ltd. Owerri.
[18]. Ononogbu, I.C (1998). Lipids and Proteins: Chemistry Methodology Metabolism Biochemical and Physiological Importance. New Africa Publishing Co. Ltd. Owerri.
[19]. Sam, O. (1999). Post Harvest Loss Prevention. The Role of Investment Capital. Proceeding of Paper Presented at the 22nd Annual NIFST Conference, 25th -27th October, 1999 at Abuja.
[20]. Scanlin, D. (1997). The Design, Construction and use of an Indirect, Through-pass, Solar Food Dryer. Homebrew (Vol. 57, p. 22). Appalachian. Available from http://www.homepower.com/view/?file=HP57_pg62_Scanlin
[21]. Sharma, A., Chen, C. R and Lan, N.Y.V. (2009). Solar Energy Drying Systems. Department of Mechanical Engineering, Kun Shan University, 949, Da-Wan Road, Yung-Kang city, Tainan Hsien 71003, Taiwan.
[22]. Sharma, M., Rashid, S. U., Ali, S. Z., Sagar, S., & Devi, R. (2016). Solar Panel with Sun Position Tracking. International Journal for Innovative Research in Science and Technology.
[23]. Shivhare, U.S., Gupta, A., Bawa, A.S. and Gupta, P. (2000). Drying characteristics and product quality of okra. *Drying Technology*, **18** (1&2), 409-419.
[24]. Weiss, W. and Buchinger, J (2002). Solar Drying. Austrian Development Cooperation, Austria. Available from <http://t.aee-intec.at/0uploads/dateien 553.pdf>