The International Journal of Engineering and Science (IJES)
|| Volume || 10 || Issue || 1 || Series I || Pages || PP 18-23 || 2021 ||
ISSN (e): 2319-1813 ISSN (p): 20-24-1805

Construction of Solar Dryer for Drying Agricultural Produce: Tomato Slices

Abdullahi Zubairu Abdulhamid[1], Ado Yahaya Sumaila[2], Inuwa Aliyu Faragai[3] and Sani Garba Durumin-Iya[4] Turado Surajo Abubakar[5]
[1235]Kano University of Science and Technology, Wudil, Kano State, Nigeria,.
[4]Sule Lamido University Kafin Hausa, Jigawa State, Nigeria,

--***ABSTRACT***--
This research dwells on the construction and performance evaluation of mixed-mode solar dryer for Tomato Slices at Kano University of Science and Technology, Wudil. A mixed-mode solar dryer utilizes direct solar radiation from the sun as well as inputs heat from the solar collector inlet which is directly connected to the dryers and at the same time the drying cabinet absorbs solar energy directly through the transparent glass. The results obtained during the test period revealed that the temperature inside all the dryers was much higher than the ambient temperature during most hours of the day-light. However, the temperature risen up inside the drying cabinet was up to 63.1°C with one inlet and also 68.8°C with two inlets occurred within the hour immediately after 12.00 noon. The capacity of the dryer is 0.2kg of products per tray while the inlet temperature is identified to play a crucial role in the solar dryer performance.

Keywords: tomato slices, solar energy, dryer, mixed mode, performance evaluation.

Date of Submission: 28-12-2020 Date of Acceptance: 09-01-2021

I. INTRODUCTION

The use of solar energy to dry crops is nothing new in the tropics as many edible and even cash crops such as cocoa, and coffee beans have traditional been dried on racks placed in sun .Although the traditional sun drying process is common and widely embraced by all, however, the process is shown and sometimes incomplete under unfavourable climate condition (Abdulelah All Al-Jumaah, Abdullah Mohamed Aslri, 2010). Often the drying products are subjected to noxious effects of dust, dirt, and insect infestation. As a result of inadequacies of the open sun drying process, research effort on drying agricultural produce have been on the increase over the years in order to develop and produce an economical effective and systemized method of drying (A. Salaudeen, 2015).

Owing to the higher level of exhaustion in the conventional energy sources such as: chemical energy, thermal energy and petroleum energy, solar energy is rapidly becoming the main alternative source of energy. The availability and accessibility of the solar energy has greatly assisted in improving the techniques for the preservation of agricultural products. (E.K. Akpinar and F. Kocyigit 2010)

Drying is a simple technique for preserving crops at a very low cost that might be otherwise spoilt. Although, the solar air collector is a very important component in the solar drying system, much attention has not been drawn during dryer design previously. In principle, the performance of solar dryer depends on the several operating conditions such as the climate condition, collector orientation, the thickness of the cover material, wind speed, length and depth of the collector, and the type of material used for the absorbers (E.K. Akpinar and F. Kocyigit 2010)For this reason, this research has dealt with the optimization of the design, material selection, and required parameters to enhance the efficiency of the designed solar dryers.

Tomatoes dried using solar dryer is good in test, color and ordor over tomatoes dried in an open air (S. Tabassum et al.,2019).

In this paper we used two dryers one with one collector and the other with two collectors and analysed the results.

II. MATERIALS AND METHODOLOGIES

The drying chambers consist of chimney, tray and transparent glassing. The drying cabinet alongside the structural support of dryer was built from wooden materials which could withstand the unfavourable weather condition. Glass was selected as the glazing material for additional heating at the drying chamber because of its high transitivity to short wave radiation. Tomato samples were selected randomly from market and sliced with a sharp knife. The slices were cut to a thickness of approximately 0.02 m and 0.01m by using a vernier. From these sliced tomatoes, a random sample was selected, and placed gently onto the perforated base of the drying chamber in one slice depth in order to represent the thin-layer drying process. Then this perforated base was placed inside the drying chamber.

2.1 **Mathematical modelling of tomato in thin-layer drying.**

Clearly suitable constructed models can be use to help with the design of new dryers and to promote the more efficient use of existing dryers, models are tools to assist in learning solving problems and communicating in the seventeen centurty, coordinated turned led to mathematical functions, which are the bass for the modern science and technology. Mathematical representation of individual component is integrated into a dynamic numerical system.
Thus, system of algebraic, differential and integral equation can be use to calculate the response of physical system to arbitrary forcing function (Frank and Jan, 1978).
To carry design calculation and size of solar dryer, the following assumption and condition were made as follows

Quantity of water to be removed: Mass of initial water content was calculated using the following equation

$$m = (m1 \times x)/100$$

Where
Mass of bone-dry product was calculated as follows:

$$md = x - m$$

Initial moisture content (db) was calculated as follows:

$$m1 = \frac{m1}{100 - m1} \times 100$$

Final moisture content was calculated as follows:

$$m2 = \frac{m2}{100 - m2} \times 100$$

The mass of water to be removed during drying was calculated using following equation

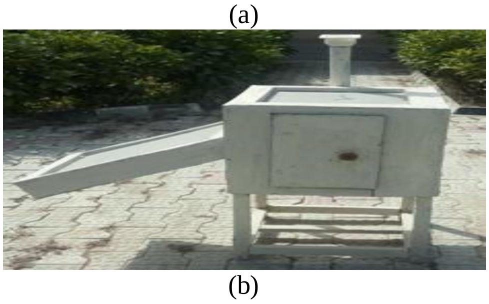
$$mw = \frac{(m1 - m2)}{100} \times x$$

2.1 Equipment and Instruments

2.1.1 Solar dryer

The indirect natural convective solar dryer was used for the drying of the tomato slices in a thin-layer. Plate 1. (a) with two inlets, and Plate 1. (b) with one inlet.

(a)



(b)

2.1.2 Sensitive balance: – 620 with 620 g capacity and 0.01 g accuracy was used for periodic weighing of tomato slices during the drying process and recording the weight loss.

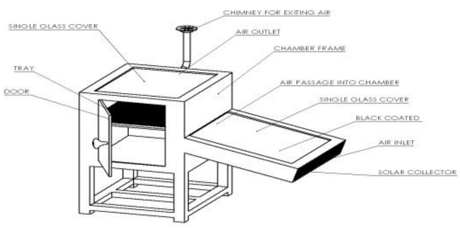
2.1.3 LCD Digital thermometer: H-9283 Multi-thermometer -50 to 300 and -58 to 572, was used to measured the temperatures change in the solar dryer during the trial.
2.1.4 Digital hygrometer: Max-Min Thermo Hygro-clock thermometer TA218, was used for ambient relative humidity measurement.
2.1.5 Anemometer: The TMA10A is a device used for measuring wind speed and directions, It is also a common weather station instrument. The term is derived from the Greek word *anemos*, which means wind, and was used to describe any wind speed during the trial, use it to check air velocity FPM (Feet per minute), air volume (flow) CFM (Cubic feet per minute).
2.1.6 Solar Power Meter: TM206 Solar Power meter is a device design to measure the solar radiation falling on a horizontal surface in watts per square meter (W/m^2).
2.1.7 Digital Multi-Sensor: The 5in 1 digital multi-sensor meter has designed to combine the functions of Sound level, Light, Humidity, Temperature and Digital Multimeter.

III. GENERAL DESCRIPTION OF THE SOLAR DRYER

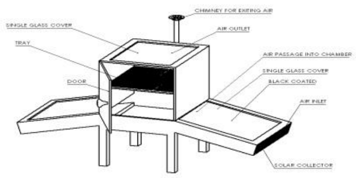
The constructed solar dryer consists of two major compartments or chambers being integrated together. The solar collector compartment, which can also be referred to as the air heater, and the drying chamber, designed to accommodate layers of drying tray on which the tomato are placed for drying.

In this solar dryer constructed, the greenhouse effect and thermo siphon principles are the theoretical basis. There is an air vent (or inlet) to the solar collector where air enters and is heated up by the greenhouse effect, the hot air rises through the drying chamber passing through the tray and around the tomato, removing the moisture content and exits through the air vent (or outlet) near the top of the shadowed side. The hot air acts as the drying medium, it extracts and conveys the moisture from the tomato to the atmosphere under natural convection.

The sectional and orthographic view, and isometric view of the constructed solar dryer are shown below in Fig 2 (a) and (b) respectively, and Plate 1 (a) and (b) shows the constructed solar when it is been placed under the sun during the testing period.



(a)



(b)

Figure 2: Sectional view and the orthographic view of the constructed mixed-mode solar dryer (a) with one inlet and (b) with two inlets

IV. RESULT AND DISCUSSION

The temperature in each of the following parts of the dryers was determine inside the chamber (T_{IN} °C), the ambient temperature (T_{AM} °C), and the relative humidity inside the chamber (RH_{IN}%), the ambient relative humidity (RH_{AM}%), and the solar intensity (I (W/M^2).

4.1 Result

Tables 1 and 2 as well as figures 1 to 4 below shows the results obtained for Temperature, Relative Humidity and Solar Intensity measurement. (a) is for One vent, while (b) is for two vents. The temperature is in degree Celsius (°C), the relative humidity is in (%), Solar intensity is in (W/M^2) and the time is recorded in 24 hour format.

Table 1: Results of Measurement of Temperature, Relative Humidity and Solar Intensity on 13th May, 2019 for One Vent

S/N	TIME(h)	M_1(g)	M_2 (g)	M_{AV} (g)	M_L (g)	T_{IN}(°C)	RH_{IN}%	T_{AM} (°C)	RH_{AM}%	I(W/M²)
1	9:00	52.3	47.7	50	-	37.6	36	30.5	38	140.2
2	10:00	50.4	45.6	48	2	42.5	35	34.3	37	153.5
3	11:00	47.2	42.5	44.85	3.15	49.2	32	37	35	170.1
4	12:00	44.7	39.1	41.9	2.95	62.5	31	38.2	34	180.3
5	1:00	40	34.1	37.05	4.85	63.1	30	40.1	33	197.3
6	2:00	36.4	30.6	33.5	3.55	52.8	29	39.5	31	197
7	3:00	33.6	27.8	30.7	2.8	50	27	38	29	184.3
8	4:00	31.5	26.1	28.8	1.9	41.6	25	37	27	111.3

Table 2: Results of Measurement of Temperature, Relative Humidity and Solar Intensity on 13th May, 2019 Two Vent

S/N	TIME(h)	M_1(g)	M_2 (g)	M_{AV} (g)	M_L (g)	T_{IN}(°C)	RH_{IN}%	T_{AM} (°C)	RH_{AM}%	I(W/M²)
1	9:00	64.9	56.1	60.5	-	38.3	36	30.5	38	140.2
2	10:00	62.1	53.7	57.9	2.6	43.3	35	34.3	37	153.5
3	11:00	58.3	49.6	53.95	3.95	56.9	33	37	35	170.1
4	12:00	53	44.9	48.95	5	63.6	32	38.2	34	180.3
5	1:00	46	38.9	42.45	6.5	68.8	31	40.1	33	197.3
6	2:00	42.1	35.4	38.75	3.7	54.8	29	39.5	31	197
7	3:00	39.7	33.2	36.45	2.3	54.5	28	38	29	184.3
8	4:00	38	31.9	34.95	1.5	42.5	25	37	27	111.3

The following graphs were plotted based on the above data.

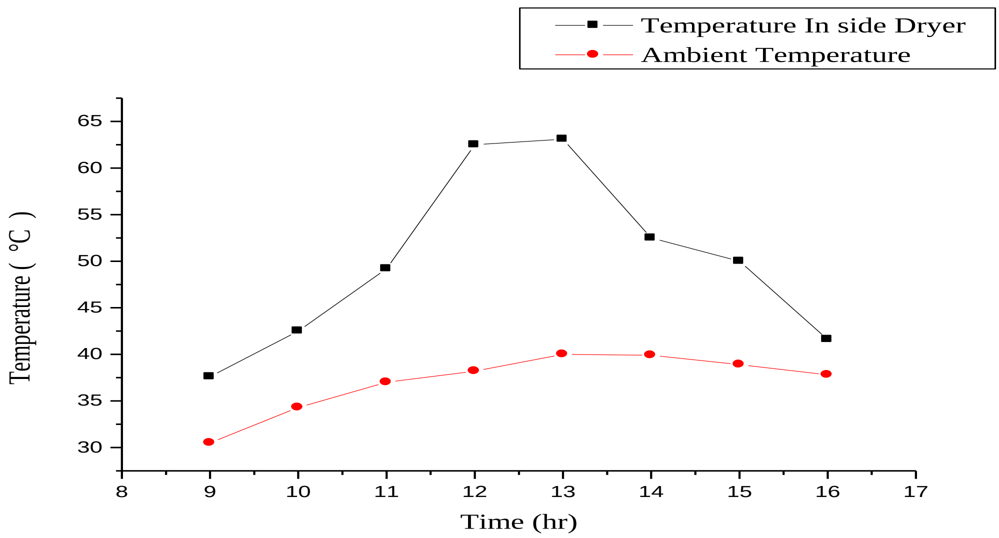


Figure 1: The ambient temperature and temperature of the dryer with one inlet

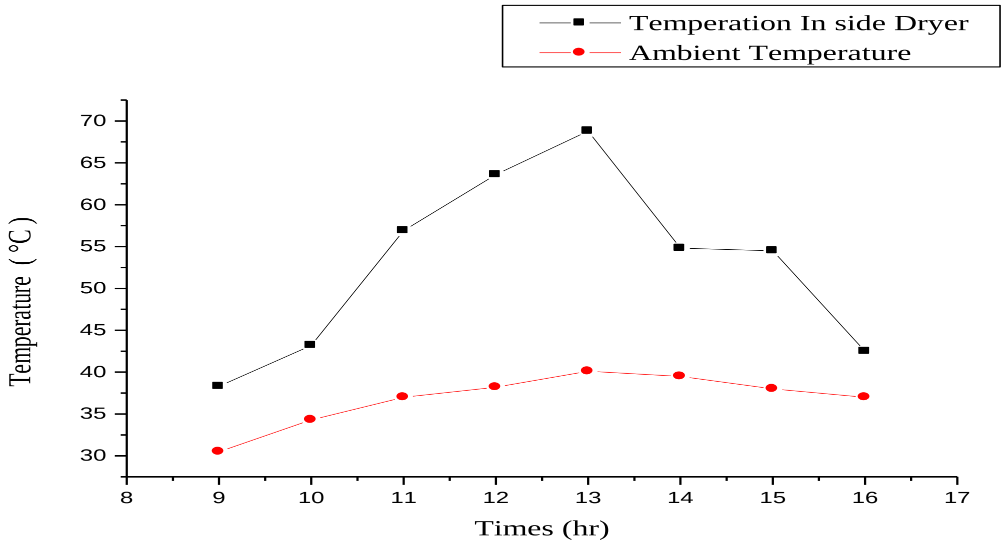
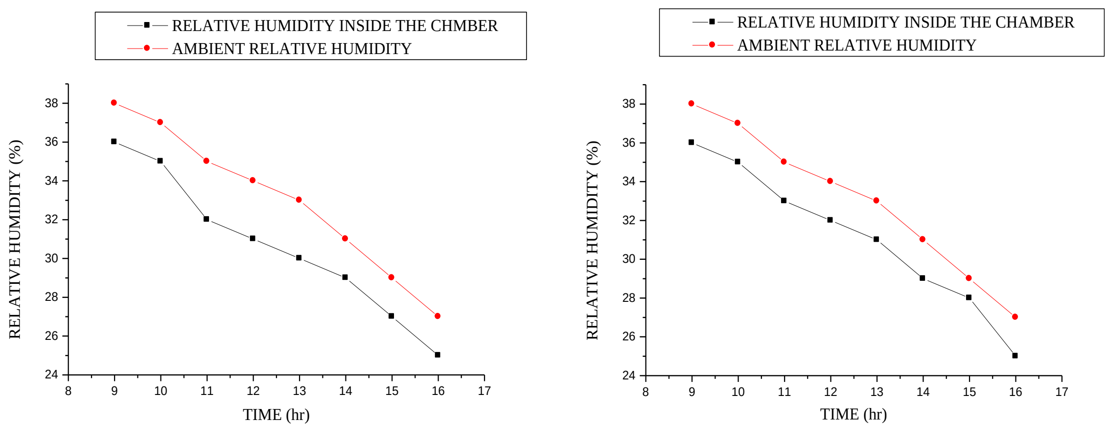


Figure 1: The ambient temperature and temperature of the dryer with two inlets



(a) (b)

Figure 3: The Relative Humidity and Ambient Relative Humidity (a) with one inlet and (b) with two inlets

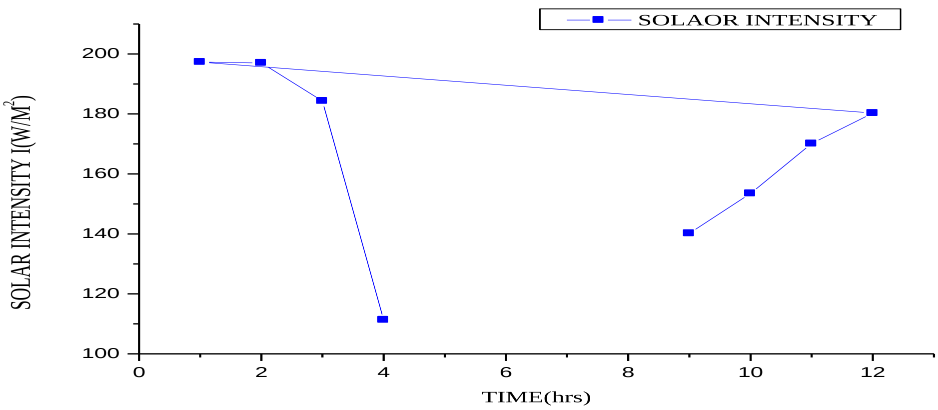


Figure 4: The Solar Intensity

Figure 4 Show Solar intensity variation

4.2 Discussion

The optimal drying chamber temperature range for tomato drying is 40°C– 80.1°C (Amin et. Al.,2011). Results from Tables 1 and 2 and Figures1 and 2 shows the temperature in the drying chamber reached a maximum value of 63.1°C and 68.8°C at 13:00hrs. This value shows the dryer's performance as a consequence of weather conditions of Kano University of Science and Technology, Wudil. The recorded temperature after sunrise indicates that, the drying chamber temperature is comparable to the optimal drying chamber temperature range.

The relative humidity of the drying chamber is the amount of moisture content of the air within the drying chamber at a given time. It depends on dew point and temperature. The optimal drying chamber relative humidity range for tomato drying is 20% − 60% (Amin et. Al., 2011). From our results in table 1 and Figure 2, the relative humidity in the drying chamber reached a minimum value of 25% and 25% at 16:00hrs. Hence, the drying chamber relative humidity fall within the optimal drying chamber relative humidity range. The capacity of the dryer is 0.1kg and 0.121kg of products per tray. The experimental results show that while the relative humidity in the dryer was adequate for tomato drying, the temperature in the drying chamber was risen up to the optimal limit. This is due to relatively low humidity in the ambient.The set of experimental data for the studying the drying of tomato slices were performed on 13th may, 2019, the solar radiation intensity was shown in figure 4 the maximum values of solar radiation intensity were 197.3 and 197, the average value of solar radiation intensity were 180.3 respectively. the maximum values of solar radiation intensity at one day occurred at 1:00 and 2:00 respectively. the solar radiation intensity increased gradually to the maximum values and decreased during period of the drying experiment.

V. CONCLUSION

The solar dryer can easily be constructed from the local materials that are less expensive, the temperature of the drying chamber remained higher than the ambient temperature throughout the experiment, while the relative humidity remained higher than the relative humidity in the ambient temperature. The drying chambers reached a maximum temperature of 63.1°C and 68.8°C while the relative humidity reached a minimum value of 25 % and 25 % within active drying hours, which is a good condition for drying of tomatoes.

REFERENCE

[1]. Abdulelah All Al-Jumaah, Abdullah Mohamed Aslri (2010) Design and construction of a solar drying system for food preservation

[2]. Amin et. Al(2011)Mathematical Modelling of Thin Layer Drying Kinetics of Tomato Influence of Air Dryer Conditions. International Transaction Journal of Engineering,Management, and Applied Sciences and Technologies. 2(2): 2228-9860.

[3]. Akpinar E.K., and Kocyigit, F.,(2010). Energy and exergy analysis of a new flat plate solar air heater having differentobstacles on absorber plates. Applied energy. 87(11): 3438-3450.

[4]. Alamu, O.J; Nwaokocha, C.N and Adunola, O. 2010. Design and construction of a domestic passive solar food dryer, Leonardo Journal of Sciences, p. 71-82.

[5]. Bolaji, B.O and Olalusi A.P (2008).Performace evaluation of a mix-mode solar dryer, journal of technology, A publication of Assumption University, Bangkok Thailand 11(4):225-231

[6]. Eze, J. I. and Agbo, K.E (2011). Comparative Studies of Sun and Solar Drying of Peeled and Unpeeled Ginger. American Journal of Scientific and Industrial Research, 2(2):136-143

[7]. Fudholi, A., Othman, M. Y., Ruslan, M. H., Yahaya, M., Zaharim, A. and Sopian, K. (2011).Design and testing of solar dryer for Drying Kinetics of seaweed in Malaysia.Journal of recent research in Geography, Geology, Energy, Enviromental and Biomedicine, 119-125P.

[8]. Krishnananth, S. S. and Kalidasa, K. M. (2012). Experimental Study on Double Pass Solar Air Heater with Thermal Energy Storage. Journal of Saud University- Engineering Sciences, 25(2):135-140

[9]. Lukman, I. (2010). Design and Construction of a Solar Grain Dryer. (Unpublished) B.Eng Project Report. Department of Mechanical Engineering Ahmadu Bello University, Zaria.

[10]. Olaleye, D.O. 2008. The design and construction of a solar incubator, Project Report,submitted to Department of Mechanical Engineering, University of Agriculture,Abeokuta.pp 11-19

[11]. Rajkumar, P. (2007). Comparative Performance of Solar Cabinet, Vacuum Assisted Solar and Open Sun Drying Methods. (Unpublished) Thesis, Department of Bioresource Engineering, Mc Gill University, Montreal Canada.

[12]. Raju, R. V. S., Reddy, R. M. and Reddy, E. S. (2013).Design and fabrication of efficient solar dryer. Journal of Engineering research and Applications, 3(6): 1445-1458P.

[13]. Salaudeen, A. (2015). Design, Construction and Testing of a Direct Solar Dryer. (Unpublished) Post Graduate Diploma in Engineering Project Work, Department of Mechanical Engineering. Ahmadu Bello University, Zaria.

[14]. S. Tabassum, M.S Bashar, M.S. Islam, A. Sharmin, S.C. Debnath, S. Parveen, S.A.A. Khanom and M. Khanam (2019). Design and Development of Solar Dryer for Food Preservation, Bangladesh J. Sci. Ind. Res. 54(2), 155-160, 2019

[15]. Svenneling, J. (2012). Constructing a Solar Dryer for drying of pineapple; Implementing a solar dryer for sustainable development in ghana.Karlstands University, Netherland.

[16]. Sexena, A. and Goel, V. (2013).Solar air Heater with thermal heat storages, Chinese Journal of Engineering, Volume 2013, Article ID 190279.

[17]. Vidya, S., R., R., Meenakshi, R.R., and Siva R.E., (2013). Design and Fabrication of Efficient Solar Dryer. International Journal of Engineering Research and Applications.3 (6):1445-1453