

**DESIGN, CONSTRUCTION AND TESTING OF DIRECT SOLAR DRYER**

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**ABSTRACT**

The solar drying system utilizes solar energy to heat up air and to dry any food substance loaded, which is beneficial in reducing wastage of agricultural products and help in preservation of agricultural products. Based on the limitations of the natural sun drying for instance exposure to direct sunlight, liability to pests and rodents, lack of proper monitoring and the escalated cost of the mechanical dryer, a solar dryer is therefore developed to cater for this limitation. The dryer is composed of solar collector (air heater) and a solar drying chamber constraining rack of three cloth (net) trays both being integrated together. The air allowed in through air inlet is heated up in the solar collector and channeled through the drying chamber where it is utilized in drying. The dimension of the dryer is 90cm x 80cm x 100cm cm (length x width x height). Locally available materials were used for the construction, chiefly comprising of wood (gmelina), glass, aluminum metal sheet, copper and net cloth for the trays. The solar dryer was tested to evaluate its performance. The test results gave temperature above 44°C in the drying chamber and the moisture content of 0.25kg of plantain reduced to about 12.5% in three days of 7 hours each day of drying. The drying rate was 0.998kg/h solar dryers produce well-dried products with reasonably long-life storage. When used, the degree of losses due to insect infestation and contamination becomes insignificant.

**KEYWORDS:** Construction, Moisture content, Optimum temperature, Plantain, Solar dryer

**INTRODUCTION**

Solar energy for drying has not been widely commercialized yet due to expensive investment, limited time and intensity of incident radiation, low skilled manpower for drying operation and poor maintenance of equipment. The main and primary reason however is that solar dryers were not designed keeping economic viability in mind. A variety of solar dryers with different types and sizes create uncertainty in the mind of users. Therefore, it is important to collect all the details of solar dryers of different types so that their usefulness for different applications may be taken into account (Hisler, 2009).

Most developing countries are unable to solve their food problems for the entire population because of the rapidly increasing number of people in their respective territories. This rapid population increase has a direct impact on food balance. The quality and quantity of food grains are deteriorating because of poor processing techniques and shortage in storage facilities. To maintain the right balance between food supply and population growth, reducing food losses during production time is mandatory. However, maximizing the food production capabilities of small farmers in rural areas is difficult. To solve the problem, drying has become one of the main processing techniques used to preserve food products in sunny areas. However, traditional open sun drying has some disadvantages. For the past few years, scientists and researchers have been trying to find the best alternative to overcome this problem. They invented various kinds of solar dryers for agricultural

products and have continuously worked to improve these dryers (Rahman *et al.*, 2008). The Earth has abundant solar radiation. In recent years, the use of solar energy has become more popular. Solar energy can be used in various processes such as drying, heating, cooking, and distilling. In terms of energy application, solar energy is categorized into electrical and thermal applications. In the agricultural sector, the use of solar thermal systems to conserve grains, fruits, and vegetables is feasible, economical, and ideal for farmers in many developing countries (Schneider *et al.*, 2013).

In the two stages of the drying process, the first phase occurs when heat is applied to the surface of the drying material at a constant rate, and the second process involves decreasing the drying rate (El-Sebaai *et al.*, 2012).

Using a solar dryer is also advantageous for drying foods, vegetables, and grains so that they can be stored for a long time. Comparing solar drying and open sun drying, the former has many advantages compared with the latter. For example, solar drying increases the quality of products. Solar dryers in different sizes and types are used to dry various agricultural materials. Therefore, dryer selection is very important in this sector as the economic aspect should also be considered (Sharma *et al.*, 2009).

Renewable energy can play an effective role to meet energy demand. Among all, solar energy is most reliable and environmental friendly. We can use it as solar photovoltaic (PV), solar thermal for pumping and drying crops in agricultural sectors (Mekhilef *et al.*, 2013). Drying is an essential process in the conservation of agricultural products. In the drying sector, the supply and demand of energy is an important consideration. Solar energy storage can minimize the gap between supply and demand in this case. At steady state conditions, more efficient and cost-

effective dryers play a vital role in substituting for the demand for fuel in many developing countries. Solar drying has very few barriers that can be improved and is already being applied in the agricultural sector with positive results (Huda *et al.*, 2014).

Having a solar storage system is important in energy conversion and is responsible for drying many agricultural products even when direct sunlight is not available (Bal *et al.*, 2014). In drying systems, the equilibrium theoretical model does enhance the understanding of the physics of moisture sorption. Purely empirical equations for specific conditions offer better alternatives until fairly accurate theoretical or semi-theoretical models are developed. The models have fallen short of predicting accurately the exact processes involved in drying, due to over implication of assumptions. These models for specific products and conditions offers better predictions. In this study some established moisture equilibrium models are mentioned (Haslem *et al.*, 2010).

To sustain the balance between population growth and food supply, food losses during harvesting and marketing should be minimized. The quality and quantity of agricultural produce suffer due to poor processing methods and shortage of storage facilities. Many developing countries suffer considerable losses on the agricultural front. It is mentioned that post harvesting loss of fruits and vegetables in developing countries is about 30–40% of total production (El-Sebaai *et al.*, 2012). Drying is one of the important preservation techniques for fruits and vegetables. Removing water by drying is the oldest technique used in many applications such as wood pulp drying for making paper, drying for food preservation and drying building materials Sharma 2009. The energy for drying comes from various sources, namely, fossil fuel, electricity,

natural gas, biomass and solar energy therefore, the topic of this review work comes under the application of applied energy. These thermal drying methods account for 10–20% of total industrial energy consumption in the developed world (Mekhilef *et al.*, 2013). Fossil fuels pollute the environment and the guarantee of limitless availability of such fuels is doubtful (Huda *et al.*, 2014). The aim of this study is to design a solar dryer which can be easily moved from place to place and is suitable for drying agricultural products.

## MATERIALS AND METHODS

### Materials

The following materials were used for the construction of the solar dryer:

**Wood** -as the casing of the entire system; wood was selected being a good insulator and relatively cheaper than metals.

**Glass** -as the solar collector cover. It permits the solar radiation into the system but resists the flow of heat energy out of the system.

**Net- cloth and wooden frames for constructing the trays Hinges and handle for the dryer's door Paint** (black and orange).

The solar food dryer was constructed making use of locally available and relatively cheap materials since the entire casing is made of wood and the cover is glass, the major construction work is carpentry works. The following tools were used in measuring and marking out on the wooden planks: Carpenter's pencil, Steel tapes, Steel meter rule, Vernier caliper, Steel square, Scriber, Hand saws, Jack pane, Wood chisel, Mallet, Hammer, Pinch bar and pincers. The construction was made with simple butt joints using nails as fasteners and glue where necessary. The construction was sequenced as follows for the wood work: Marking out

on the planks to cut into desired shape; Cutting out the already marked out parts; planning of the cut out parts to smoothen the surfaces; Joining and fastening of the cut out parts with nails and glues. The glass used was clear glass with 4 mm thickness. The glass was cut into size of 56 x 90 cm size to act as solar collector cover. The trays were made with wooden frames and net cloth to permit free flow of air within the drying chamber. Four trays were used with average of 15 cm spacing arranged vertically one on top of another, the tray size was 35 x 50 cm. The interior of the solar food dryer was painted black with tar to allow for absorption of heat energy while the exterior was painted orange to minimize the adverse effects of weather and insect attack on the wood and also for aesthetic appeal.

## DESIGN CONSIDERATION

**Temperature-** The design was made for the optimum temperature for the dryer to dry plantain  $T_0$  of  $60^{\circ}\text{C}$  and the air inlet temperature or the ambient temperature of dryer was taken as  $T_a = 37^{\circ}\text{C}$

**Efficiency-** This is defined as the ratio of the useful output of a product to the input of the product.

**Glass and flat plate solar collector-** Solar collector glazing material was used. Collector glazing is exposed to high temperatures, long time outdoor exposure, impacts from vandals, while also requiring high light transmission and reasonable cost; 4mm thick transparent glass was used

**Design of Drying Chamber-** The drying chamber was made as spacious as possible with average dimension of 57 x 80 x 39 cm with air vent out of the cabinet of XX

**Design of Solar Collector-** The design of the solar collector was made as spacious as possible of average dimension of 88 x 49 x 15 cm. The solar collector and drying

chamber are painted black because black colour is a good absorber of heat and poor radiator of heat, so it absorbs the solar energy falling on the solar collector and converts it to heat energy required for drying plantain in the drying chamber.

**Insulation-** The insulating material was plywood of 2.5 cm thick, it is a good insulator as well as environmentally friendly. It is corrosion free and does not have any carcinogenic effects. Absorber Plate- GI Sheets were used as absorber plate placed inside the solar collector and painted black for better solar absorption.

**Net-trays-** Net type trays were selected as the dryer trays to aid air circulation within the drying chamber. Four trays were placed to keep plantain for drying purpose. The tray dimension is height of 7 cm and length of 50 cm. the gap between each tray is 15 cm.

## Formulas and Calculations

### 1. Calculation of Angle of Tilt ( $\beta$ ) of Solar Collector:

Angle of tilt ( $\beta$ ) OF solar collectors is given by

$$\beta = 10^\circ + \text{lat } \phi$$

Where  $\text{lat } \phi$  = latitude of the place where the solar dryer was designed, which is Yaba College of Technology, Yaba, Lagos. Here,  $\text{lat } \phi$  is  $6.52^\circ\text{N}$ .

Hence the suitable value of  $\beta$  used for the collector is given as:

$\beta = 10^\circ + 6.52^\circ = 16.52^\circ$  facing due South direction.

### 2. Calculation of Drying Rate ( $\frac{dM}{dt}$ )

$$\frac{dM}{dt} = \left( \frac{M_i - M_f}{t} \right) \times 100\%$$

$M$  = mass

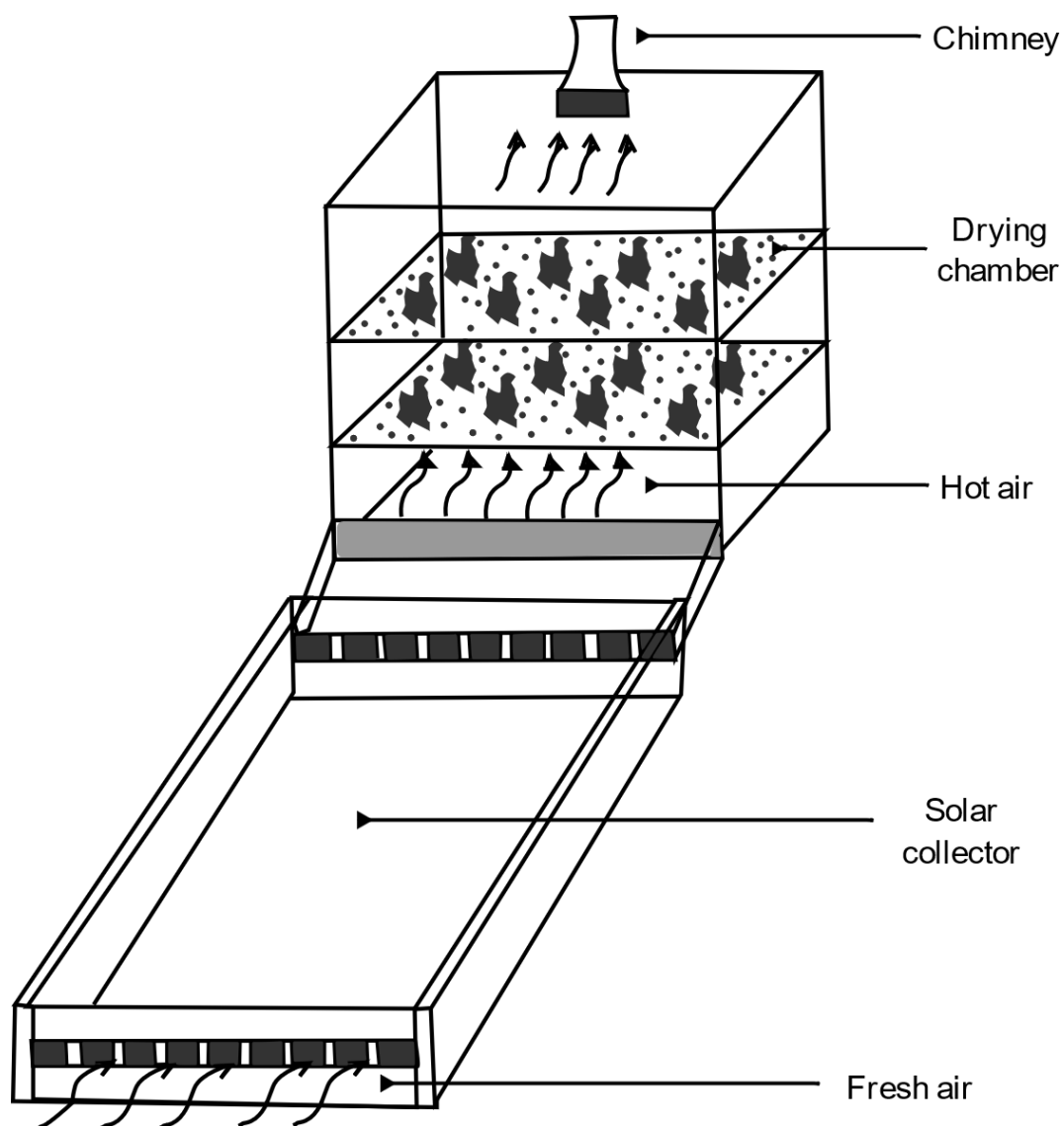
$M_i$  = initial mass

$M_f$  = final mass  $t$  = time interval

The solar dryer is designed to help in the reduction of the moisture content preserved in it. Hence, there will be an air vent or inlet to the solar collector where air enters and it will be heated up by solar collector. The hot air will rise through the drying chamber, pass through the trays and around the farm produce reducing the moisture content and exits through the outlet near the top of the chamber

The materials for making the solar dryer are cheap and easily obtainable in the local market. The solar dryer is shown in Figure 1. The product is located on trays or shelves inside an opaque drying chamber. Solar radiation is thus not incident directly on the crop. The air is heated by a solar collector connected to a drying chamber that contains agricultural product. The product remains under shade and isolated from the ambient air. The drying process occurs by the exchange of water between the product and the flowing hot air. The testing of the solar plantain dryer was done for three days. The solar dryer was placed outside with the collector facing the direction of the Sun. The collector was positioned at an angle of  $17^\circ$  to the horizontal. About five pieces of plantain were peeled and sliced weighed 0.25 kg were arranged on the drying bed in a single layer to avoid moisture being trapped in the lower layer. The dryer chamber closed and seals placed in position. The result obtained for hourly reading of 7 hours every day is tabulated in Tables 1-3

## RESULTS AND DISCUSSION



*Figure 1: The constructed Solar Dryer*

**Table 1: Daily Hourly Measured Temperatures**

| Daily | Time(hrs) | T <sub>a</sub> | T <sub>c</sub> | T <sub>c</sub> | T <sub>p</sub> | M <sub>1</sub> | M <sub>2</sub> | M <sub>A</sub> |
|-------|-----------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| DAY 1 | 10.00     | 34             | 35             | 35             | 34             | 0.25           | 0.25           | 0.25           |
|       | 11.00     | 35             | 36             | 36             | 36             | 0.23           | 0.24           | 0.24           |
|       | 12.00     | 39             | 35             | 36             | 36             | 0.19           | 0.22           | 0.21           |
|       | 13.00     | 36             | 35             | 36             | 36             | 0.18           | 0.20           | 0.19           |
|       | 14.00     | 34             | 35             | 34             | 34             | 0.16           | 0.18           | 0.17           |
|       | 15.00     | 35             | 35             | 34             | 34             | 0.15           | 0.17           | 0.16           |
|       | 16.00     | 36             | 37             | 34             | 35             | 0.15           | 0.17           | 0.16           |
|       | 17.00     | 36             | 37             | 34             | 35             | 0.15           | 0.17           | 0.16           |
| DAY 2 | 10.00     | 32             | 32             | 35             | 35             | 0.15           | 0.17           | 0.16           |
|       | 11.00     | 34             | 35             | 36             | 35             | 0.14           | 0.16           | 0.15           |
|       | 12.00     | 39             | 37             | 37             | 36             | 0.13           | 0.15           | 0.13           |
|       | 13.00     | 36             | 37             | 36             | 36             | 0.11           | 0.14           | 0.13           |
|       | 14.00     | 37             | 37             | 36             | 36             | 0.10           | 0.13           | 0.12           |
|       | 15.00     | 36             | 36             | 35             | 35             | 0.10           | 0.10           | 0.10           |
|       | 16.00     | 34             | 35             | 35             | 35             | 0.7            | 0.9            | 0.8            |
|       | 17.00     | 32             | 32             | 32             | 32             | 0.6            | 0.7            | 0.7            |
| DAY 3 | 10.00     | 32             | 32             | 34             | 36             | 0.6            | 0.7            | 0.7            |
|       | 11.00     | 33             | 35             | 34             | 36             | 0.5            | 0.7            | 0.6            |
|       | 12.00     | 37             | 43             | 35             | 38             | 0.4            | 0.7            | 0.55           |
|       | 13.00     | 44             | 44             | 43             | 42             | 0.3            | 0.7            | 0.5            |
|       | 14.00     | 42             | 44             | 39             | 39             | 0.3            | 0.6            | 0.45           |
|       | 15.00     | 47             | 44             | 37             | 41             | 0.3            | 0.5            | 0.4            |
|       | 16.00     | 34             | 35             | 36             | 37             | 0.2            | 0.4            | 0.3            |
|       | 17.00     | 32             | 34             | 35             | 35             | 0              | 0.1            | 0.1            |

M<sub>1</sub>- Initial Mass

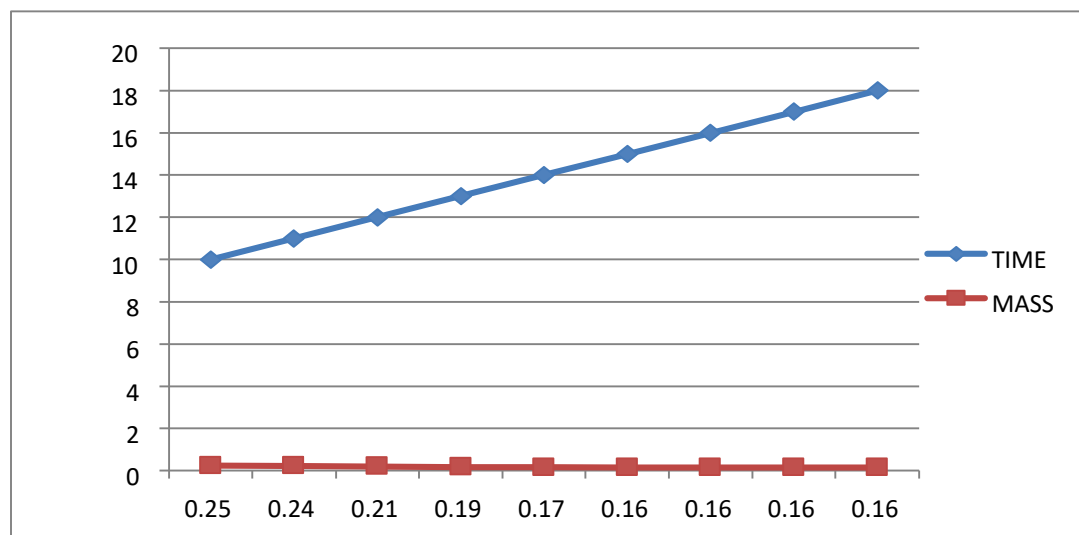
M<sub>2</sub>- Final Mass

M<sub>A</sub>- Average Mass

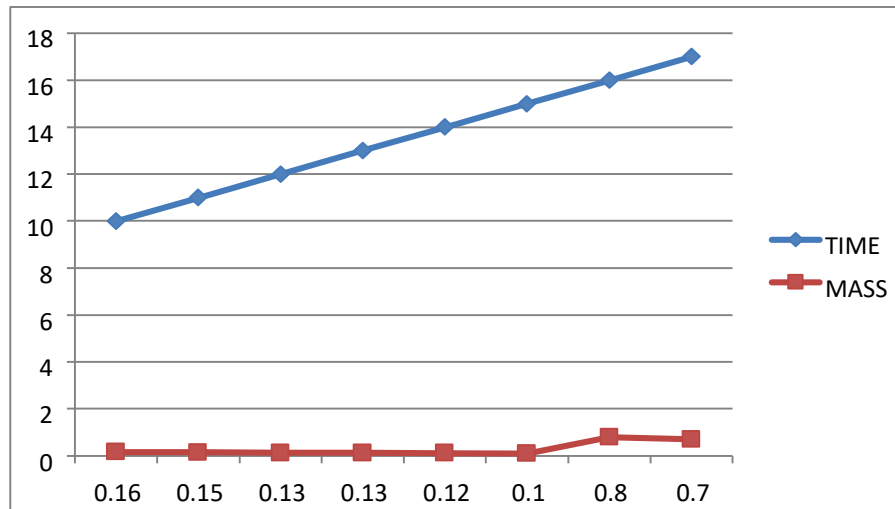




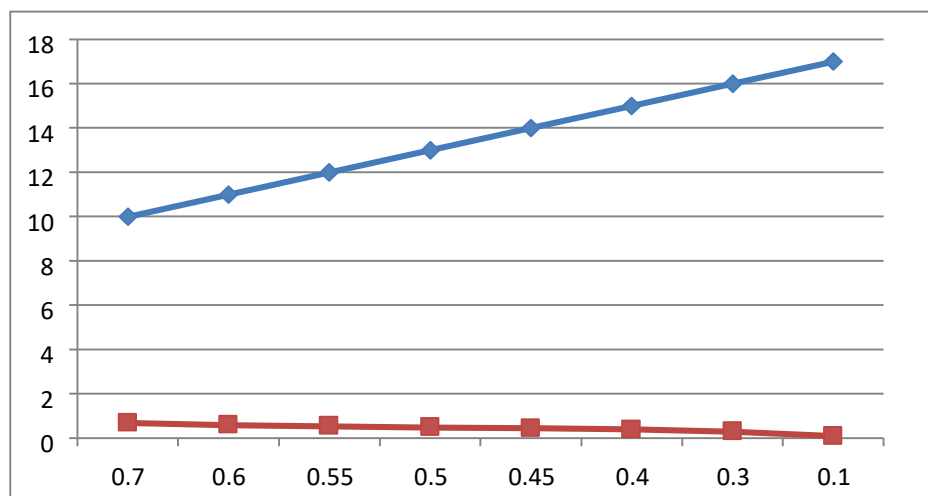
**Figure2:** picture of the plantain in the solar dryer after testing



**Fig. 3:** Day 1 of Drying



*Fig 4: Day 2 of Drying*



*Fig 5: Day 3 of Drying*

## DISCUSSION

The solar dryer shown in Figures 1 and 2 was tested within three days to evaluate its performance. During the testing period, the air temperatures at collector inlet, collector outlet, drying chamber and ambient were measured by infrared thermometer with accuracy of  $\pm 0.2^{\circ}\text{C}$  at interval of 1 hour between 11am and 5pm each day. Table 1 shows the hourly variation of the temperatures in the solar collector and the drying cabinet compared to the ambient temperature. The dryer is hottest about mid-day when the sun is usually overhead. The temperature inside the dryer and the solar

collector were much higher than the ambient temperature during most hours of the daylight. This agrees with the work of Chandan (2018), who constructed a solar drying system for mushroom preservation; also with the work of Phardi and Bhagoria (2013) in which a forced convection was applied in the mixed-mode dryer, yielding a temperature increase inside the drying cabinet of up to 64.5% for most of the hours in the noon time. Similarly in the work of Folaranmi (2008), an average of  $45^{\circ}\text{C}$  was recorded inside the drying chamber against an ambient of  $27^{\circ}\text{C}$ , which is equivalent to an increment of about 40% above ambient.



Figures 3-5 show the variation of mass with time. Figures 1 and 3 show the effect of humidity on drying capacity of the solar dryer. The mass of the agricultural produce almost remained constant when the humidity is high. There is appreciable decrease in the mass of plantain on the third day in Fig 5 when the humidity is relatively low compared with first and second day, this might be as result of large availability of solar radiation on that day. This also agrees with the work of Prakash et al. (2014) whose study was on performance analysis of Guntur red chili, where chili was dried to final moisture content of 9% wet basis from 80% wet basis. The average drying rate of the constructed solar dryer in this work was obtained to be 0.998 kg/h. In the work of Phardi and Bhagoria (2013), the performance evaluation of their mixed-mode dryer using forced convection gave a drying rate of 0.38 kg/h. Similarly, Ehiem et al. (2009), recorded a drying rate of 0.04kg/h at relative humidity of 35% using a forced convection dryer. Therefore, the performance of this dryer is quite satisfactory considering the fact that it is the natural convection type with a potential of forced convection too. This is because when the backup system is installed, it can also support a fan or a blower.

## CONCLUSION

In this study, a renewable solar dryer was constructed and tested using plantain. One of the major reasons for drying food items is to reduce water content (moist content) in them so that such food items can be preserved for future use. The results gotten from this study shows that the usage of solar dryers in the preservation of agricultural product is effective. Solar dryers produce well-dried products with reasonably long-life storage. When used, the degree of losses due to insect infestation and contamination becomes insignificant.

## RECOMMENDATIONS

Since solar drying has proved to be technically and economically feasible, It is therefore recommended;

- That a large scale solar dryer is developed to improve the acceptability of solar dryers among farmers.
- Further studies should be carried out of the use of solar dryers in the preservation of other agricultural products and its effects of the quality of such food items.

## ACKNOWLEDGEMENT

The authors are grateful to Mr Ogunfunmilayo, A.K. of the Department of Works and Services, Yaba College of Technology, Yaba, for his technical support in this study.

## REFERENCES

- Al-Juamilly, K.E.J., Khalifa, A.J. and Yassen, T.A. (2007). Testing of The Performance of a Fruit and Vegetable Solar Drying System In Iraq. *Desalination*, 209:163–170.
- Arata, A. and Sharma, V.K. (1991). Performance Evaluation of Solar Assisted Dryers for Low Temperature Drying Applications—I. Plants Description. *Renewable Energy*, 1: 729–735.
- Bal, L.M., Satya S. and Naik, S. (2014). Solar Dryer with Thermal Energy Storage Systems for Drying Agricultural Food Products: A Review. *Renewable and Sustainable Energy Reviews*, 14:2298–2314.
- Bala, B., Ashraf, M., Uddin, M. and Janjai, S (2005). Experimental and Neural Network Prediction of the Performance of a Solar Tunnel Drier for Drying Jackfruit Bulbs and Leather. *J Food Process Engineering*; 28(6):552–566.
- Basunia, M. and Abe, T. (2011). Thin-Layer Solar Drying Characteristics of Rough Rice Under Natural Convection. *Journal Of Food Engineering*, 47:295–301.

- Bolaji, B.O. and Olalusi, A.P. (2008). Performance Evaluation of a Mixed-Mode Solar Dryer. *AU J Technology*, 11(4):225–231.
- Brenndorfer, B., Kennedy, L. and Mrema, G. (2008). Solar Dryers: Their Role in Post-Harvest Processing. Commonwealth Secretariat, 3(4); 120-124.
- Chandan, T. (2018). A Design and Construction of a Solar Drying System for Mushroom Preservation. *International Research Journal of Engineering and Technology*, 5(5): 548-560
- Diamante, L. P. and Munro, P.A. (1993). Mathematical Modelling of The Thin Layer Solar Drying Of Sweet Potato Slices. *Solar Energy*, 51:271–276.
- Ehiem, J. C., Irtwange, S. V. and Obeta, S. E. (2009). Design and Development of an Industrial Fruit and Vegetable Dryer. *Research Journal of Applied Sciences, Engineering and Technology*, 1(2): 44-53
- El-Sebaei, A., Aboul-Enein, S., Ramadan, M. and El-Gohary, H. (2002). Experimental Investigation of An Indirect Type Natural Convection Solar Dryer. *Energy Conversion and Management*, 43(16):2251–2266.
- El-Sebaei, A. A., and Shalaby S. M. (2012). Solar Drying of Agricultural Products: A Review. *Renewable and Sustainable Energy Reviews*, 16:37–43.
- Esper, A. and Mühlbauer, W. (2009). Solar Drying—An Effective Means of Food Preservation. *Renewable Energy Elsevier*, 15: 95–100.
- Exell, R.H. and Kornsakoo, S. (1980). Basic Design Theory for a Simple Solar Rice Dryer. *Renewable Energy Review*, 1:101–110.
- Ferreira, A.G., Maia, C.B., Cortez, M.F. and Valle, R.M. (2008). Technical Feasibility Assessment of a Solar Chimney for Food Drying. *Solar Energy*, 82:198–205.
- Folaranmi, J. (2008). Design, Construction and Testing of a Simple Solar Maize Dryer. *Leonardo Electronic Journal of Practices and Technologies*, 13: 122-130.
- Goyal, R., and Tiwari, G. (2007). Parametric Study of a Reverse Flat Plate Absorber Cabinet Dryer: A New Concept. *Solar Energy* 60:41–48.
- Gupta, P., Ahmed, J., Shivhare. U and Raghavan, G. (2002). Drying Characteristics of Red Chilli. *Drying Technology*, 20:1975–1987.
- Haslem, H., Kumar, R. and Salim, M. (2010). Studies on Semi-Cylindrical Solar Tunnel Dryers: Thermal Performance of Collector. *Applied Thermal Engineering*, 20:115–131.
- Janjai, S., and Bala, B. (2012). Solar Drying Technology. *Food Engineering Reviews*, 4:16–54.
- Maia, C.B., Ferreira, A.G., Valle, R. M. and Cortez, M.F. (2009). Analysis of the Airflow in a Prototype of a Solar Chimney Dryer. *Heat Transfer Engineering*, 30:393–399.
- Mekhilef, S., Faramarzi, S., Saidur, R. and Salam, Z. (2013). The Application of Solar Technologies for Sustainable Development of Agricultural Sector. *Renewable and Sustainable Energy Reviews*, 18:583–94.
- Midilli, A. (2001). Determination of Pistachio Drying Behaviour and Conditions in a Solar Drying System. *International Journal of Energy Research*, 25:715–25.
- Mohanraj, M. and Chandrasekar, P. (2009). Performance of a Forced Convection Solar Drier Integrated with Gravel as Heat Storage Material for Chili Drying. *Journal of Engineering Science and Technology*, 4(3):305–314.
- Ondier, G. O., Siebenmorgen, T. J. and Mauromoustakos, A. (2010) Low-Temperature, Lowrelative Humidity Drying Of Rough Rice. *Journal Of Food Engineering*, 100:545–50.
- Panwar, N., Kaushik S. and Kothari S. (2012). State of the Art of Solar Cooking: An Overview. *Renewable and Sustainable Energy Reviews*, 16:3776–85.

- Pardhi, C. B. and Bhagoria, J. L. (2013). Development and Performance Evaluation of Mixed-Mode Solar Dryer with Forced Convection. *International Journal of Energy and Environmental Engineering*, 4: 11-24.
- Prakash, T.B. and Satyanarayana, G.B. (2014). Performance Analysis of Solar Drying System for Guntur Chili. *International Journal of Latest Trends in Engineering and Technology*, 4(2): 283-298.
- Prasad, K. and Mullick S. C. (1983) Heat Transfer Characteristics of a Solar Air Heater Used for Drying Purposes. *Applied Energy*. 13:83–93.
- Rahman, F., Sopian, K., Ruslan. M., Alghoul, M. And Sulaiman, M. (2008). Review of Solar Dryers for Agricultural and Marine Products. *Renewable and Sustainable Energy Review*, 14:1–30.
- Ratti, C. and Mujumdar A. (2007). Solar Drying of Foods: Modeling And Numerical Simulation. *Solar Energy*, 60:151–7.
- Santos, B., Queiroz, M. and Borges, T. A. (2005). Solar Collector Design Procedure for Crop Drying. *Brazilian Journal of Chemical Engineering*, 22:277–84.
- Schneider, G. Yobouet Andoh, H., Kouassi Saraka, J., Kaménan Koua, B. and Toure, S. (2013). Experimental Investigation of a Solar Dryer with Natural Convective Heat Flow. *Renewable Energy*, 32:1817–1829.
- Sevik, S. (2013). Design, Experimental Investigation and Analysis of a Solar Drying System. *Energy Conversion and Management*, 68:227–34
- Sharma, A., Chen, C. R. And Lan, N. V. (2009). Solar-Energy Drying Systems: A Review. *Renewable and Sustainable Energy Reviews*, 13:1185–210.
- Sharma, V. K., Colangelo A. And Spagna, G. (2003). Experimental Performance of an Indirect Type Solar Fruit And Vegetable Dryer. *Energy Conversion and Management*, 34(4): 293–308.
- Sharma V. K., Colangelo A. and Spagna, G. (2002). Investigation of an Indirect Type Multi-Shelf Solar Fruit and Vegetable Dryer. *Renewable Energy*, 2:577–86.
- Sharma, V. K., Colangelo A, and Spagna, G. Experimental Investigation of Different Solar Dryers Suitable for Fruit and Vegetable Drying. *Renewable Energy*, 6:413–24.
- Simate, I.N. Optimization of Mixed-Mode and Indirect-Mode Natural Convection Solar Dryers (2003) *Renewable Energy*, 8:435–53.
- Singh, S. and Kumar, S. (2012). New Approach for Thermal Testing of Solar Dryer: Development of Generalized Drying Characteristic Curve. *Solar Energy*, 86(7): 1981-1991.
- Sodha, M.S., Dang A, Bansal P. K. and Sharman S B. (1985). An Analytical and Experimental Study of Open Sun Drying and a Cabinet Tyre Drier. *Energy Conversion and Management*, 25(3): 263–71.
- Tiris, C., Tiris M, and Dincer, I. (1996). Experiments on a New Small-Scale Solar Dryer. *Applied Thermal Engineering*, 16(2):183–7.
- Wittwer, S.H. (2009). Solar Energy and Agriculture. *New Trends In Research and Utilization of Solar Energy Through Biological Systems*, 16-19
- Zomorodian, A., Zare, D. and Ghasemkhani, H. (2007). Optimization and Evaluation of a Semi-Continuous Solar Dryer for Cereals (Rice, Etc.). *Desalination*, 209: 129–35.