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Construction and Performance Avaluation of an Indirect Solar Dryer for Drying Okro and Pepper

Suleiman, M[1]. and Abubakar, Y.G[2].
[1]Department of Science Laboratory Technology, College of Science and Technology, Umaru Ali Shinkafi Polytechnic, Sokoto, Nigeria.
[2]Department of Physics, Staff School, Umaru Ali Shinkafi Polytechnic, Sokoto, Nigeria.
Corresponding author: Email: ask4manir@ymail.com GSM No: +2348035626276

Abstract: *The solar drying system uses solar energy to heat up air and dry any food substance loaded, which is beneficial in reducing wastage and helps in the preservation of agricultural produce. Based on the limitations of the natural sun drying, for example, 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 to this limitation. This work presents the design, construction, and performance of an indirect solar dryer for food preservation. In the dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls and roof. The temperature inside the drying cabinet rises to about 59 ºC while that of the ambient rises up to 38 ºC - 74 ºC for about three hours immediately after 12:00h (noon). The dryer is exhibited to the sufficient sun to enable it to be able to dry food items reasonably rapid to a safe moisture level and simultaneously to ensure a superior quality of the dried farm produce. It is able to dry about 1 kg to 2 kg of fresh Okro and Pepper within 12hours while the equal quantity of the Okro and Pepper will probably take up to 24hours in an open-air to dry. Appropriate statistical tool(s) is utilized for performance evaluation.*

Keywords: *Solar, Fabrication, Performance, Dryer, Temperature.*

INTRODUCTION

Drying is one of the methods used to preserve food products for longer periods. The heat from the Sun coupled with the wind has been used to dry food for preservation for several thousand years. Solar thermal technology is a technology that is rapidly gaining acceptance as an energy saving measure in agriculture application. It is preferred to other alternative sources of energy such as wind and shale, because it is abundant, inexhaustible, and non-polluting. Solar air heaters Drying is one of the methods used to preserve food product s for longer period. The heat from the Sun coupled with the wind has been used to dry food for preservation for several thousand years. Solar thermal technology is a technology that is has been in use with simple devices to heat air by utilizing solar energy and it is employed in many applications require to moderate temperature below 80°C, such as crop drying and space heating. Drying is the oldest preservation technique of agricultural products and it is an energy intensive process. High prices and shortages of fossil fuels have increased the emphasis on using alternative renewable energy resources. Drying of agricultural products using renewable energy such as solar energy is environmentally friendly and environmental impact. Different types of solar dryers have been designed, fabricated and tested in the different regions of the tropics and subtropics. The major two categories of the dryers are natural convection solar dryers and forced convection solar dryers. In the natural convection solar dryers, the airflow is established by buoyancy induced airflow while in forced convection solar dryers the airflow is provided by using fan operated either by electricity/solar module or fossil fuel.

In many parts of the world there is a growing awareness that renewable energy has an important role to play in extending technology to the farmer in developing countries in order to increase their productivity (Waewsak et al., 2006). Traditional drying, which is frequently done on the ground in the open air, is the most widespread method used in developing countries because it is the simplest and cheapest method of conserving food stuffs. Some disadvantages of open-air drying are exposure of the foodstuff to rain and dust, uncontrolled drying, exposure to direct sunlight which is undesirable for some foodstuffs, infestation by insects, attack by animals, etc. (Madhlopa et al., 2002). In order to improve traditional drying, solar dryers, which have the potential of substantially reducing the above-mentioned disadvantages of open air drying, have received considerable attention over the past 20 years (Bassey, 1989). Solar dryers of the forced convection type can be effectively used. They, however, need electricity, which unfortunately is non-existent in many rural areas, to operate the fans. Even when electricity exists, the potential users of the dryers are unable to pay for it due to their very low income. Forced convection dryers are for this reason not going to be readily applicable on a wide scale in many developing countries. Natural convection dryers circulate the drying air without the aid of a fan. They are therefore, the most applicable to the rural areas in developing countries. Solar drying may be classified into direct, indirect and mixed-modes. In direct solar dryers the air heater contains the grains and solar energy passes through a transparent cover and is absorbed by the grains. Essentially, the heat required for drying is provided by radiation to the upper layers and subsequent conduction into the grain bed. In indirect dryers, solar energy is collected in a separate solar collector (air heater) and the heated air then passes through the grain bed, while in the mixed mode type of dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls or roof. Therefore, the objective of this study is to develop an indirect solar dryer in which the grains are dried simultaneously by the heated air from the solar collector. The performance of the dryer will also be evaluated.

MATERIALS AND METHODS

Solar drying refers to a technique that utilizes incident solar radiation to convert to thermal energy required for drying purposes. Most solar dryers use solar air heaters and the heated air is which passes through the drying chamber (containing material) to be dried. The air transfers its energy to the material causing evaporation of moisture of the material.

i. The solar dryer was designed using average short-term data obtained from the month of November.
ii. The solar dryer was designed to dry Okro and Pepper.
iii. The collector was positioned at an angle of inclination for the best year-round performance (13º N), which is the latitude of Sokoto, Nigeria.

In the light of the above the following materials which are locally available have been used:

Materials Used

Glass sheet (4 mm), Sheet metal (59 cm/93 cm), Plank wood (51 cm/95 cm), Saw dust, Cast iron (C.I.) pipes, Solar panel (12 volts), Mercury (glass thermometer), Fan (12 volts), Wires (1yard), Masking tape, Net (49/24 cm), Top bond, Ply wood (51 cm/35 cm).

CONSTRUCTION OF THE SYSTEM COMPONENTS

i. **Solar Collector**

The heat absorber (inner box) of the solar dryer was constructed using 2 mm thick aluminum sheet, painted black, is mounted in an outer box built from wooden plank. The space between the inner box and outer box is filled with saw dust material of about 40 mm thickness and the thermal conductivity of the plate is $200Wm^{-1}K^{-1}$. The solar collector assembly consists of air flow channel enclosed by transparent cover (glazing). One end of the solar collector has an air inlet vent through a pipe of 2.5cm internal diameter. The overall collector plate has a dimension of 95cm/51cm as shown in Figure 1. It also consists of heater and riser pipes arrangement. The heater and riser pipes were welded before being placed in the collector casing made from wooden plank.

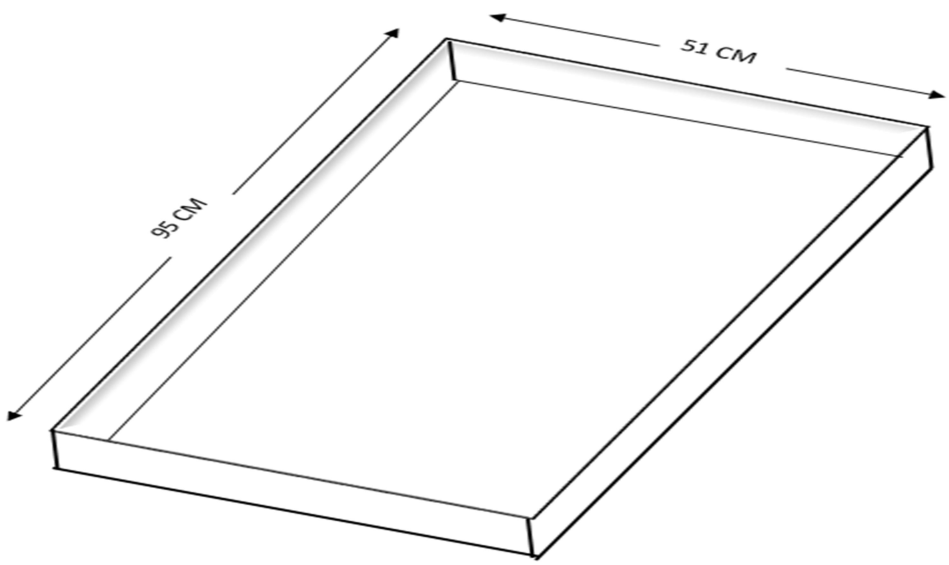

Figure1: Dimension of the solar collector.

Plate 1: Casing the collector.

ii. Top Cover

The glazing is a single layer of 4 mm thick transparent glass sheet, it has a surface area of 49cm by 93cm and of transmittance above 0.7 for wave lengths in the rage 0.2 – 2.0 µm.

***iii.* The Drying Chamber**

The drying chamber together with the structural frame of the dryer was built from wooden plank which could withstand termite and atmospheric attacks. An outlet vent was provided toward the upper end at the back of the chamber to facilitate and control the convection flow of air through the dryer. Access door to the drying rays was also provided at the back of the chamber. The schematic diagram of the drying chamber is shown in Figure 2.

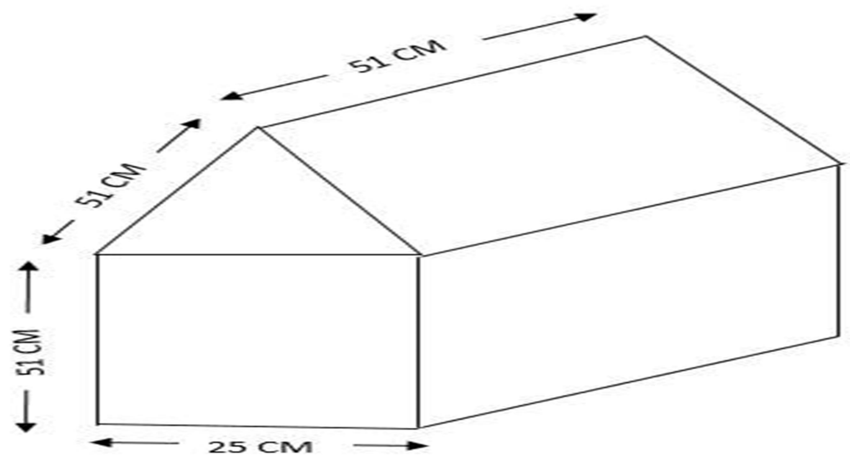

Figure 2: The schematic diagram of drying chamber.

iv. The Blowing Fan

A direct current (D.C.) Fan was connected to the collector pipes to blow the heated air from the heating cabinet to the drying chamber through the pipes in order to make the drying process fast. It is powered by a solar panel.

v. The Solar Photovoltaic Panel

A solar photovoltaic panel of (12 volts) was use to power the fan. the speed of the fan depends directly on the solar intensity, the higher the intensity the higher the speed of the fan, the lower the intensity the lower the speed of the fan.

Finally, both the constructed solar collector and the drying chamber were assembled together as shown in Plate 2 below:

Plate 2: Side view of the Construction.

TESTING OF THE INDIRECT SOLAR DRYER

In the test, solar intensity, ambient temperature, wind speed, glass temperature, air temperature, and temperature of the drying chamber. at 30 minutes intervals were measured for the analyses of the performance of the indirect solar air heater. The Experiments were carried out in front of Physics Laboratory of the Umaru Ali Shinkafi, Polytechnic, Sokoto, Nigeria for two days i.e., 16th, and 17th of November, 2021. To ascertain the performance of the indirect solar dryer by determining how long it will take to dry the Okro and Pepper, and temperature rise in the solar dryer was mounted in the early hours of the day as shown in Plate 3 below:

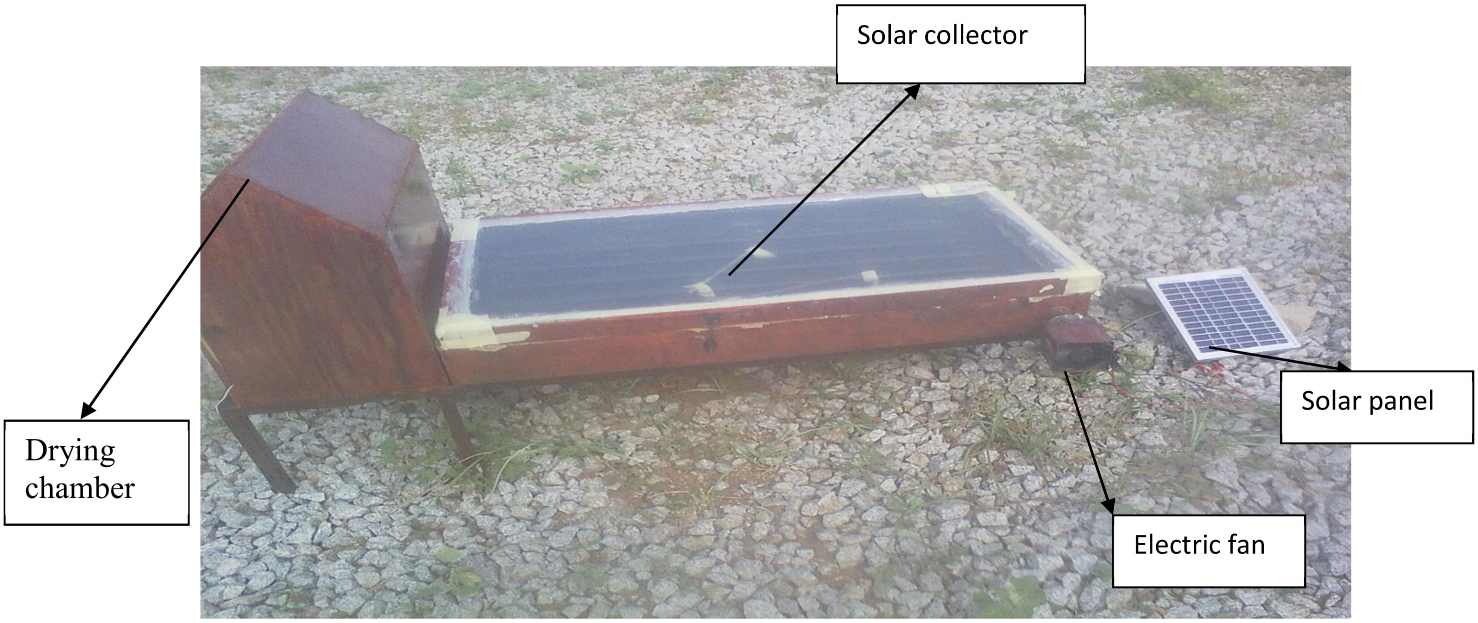

Plate 3: The Setup of the Experiment.

The readings of inside the cover temperature, air inlet temperature, ambient temperature, glass temperature, temperature of the plate and temperature of the draying chamber, were measured with the use of Mercury in glass thermometer and Digital thermometer with probe every 30 minutes. Average wind speed, insulation (H_S), were also measured using Anemometer and Pyranometer, respectively.

RESULTS AND DISCUSSION

Readings Taken from Solar Dryer

Readings of ambient temperature (t_{amb}), inner glass temperature (t_g), the temperature of the plate (t_p), temperature of the air (t_{air}), the temperature of the drying chamber (t_{ch}), solar radiation (i), and wind speed (v) were taken on the first and second days of the experiment. Results of these readings are discussed by graphical representation in the following section.

The results obtained during the test period revealed that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most hours of the day-light. The temperature rise inside the drying chamber was up to 74% for about three hours immediately after 12.00h (noon). It was able to dry 2kg and 1kg of fresh Okro and Pepper within 12hours while the equal quantity of the Okro and Pepper was dried within 24 hours in an open air drying. The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures superior quality of the dried product.

VARIATION OF THE TEMPERATURE IN THE SOLAR COLLECTOR, GLASS, AIR AND THE DRYING CHAMBER COMPARED TO THE AMBIENT TEMPERATURE

Figure 3a and 3b, the temperatures show a typical day results of the 30 minutes interval temperature variation in the solar collector and the drying chamber compared to the ambient. The dryer was observed to be hottest about mid-day when the sun was usually at maximum insulation level. The temperatures inside the dryer and the solar collector were much higher than the ambient temperature during most hours of the daylight. The temperature rise inside drying chamber was up to 58 ºC (74%) for about three hours immediately after 12.00h (noon). This indicates prospect for better performance than open-air sun drying.

Also results of solar radiation and wind speed monitored during the tests periods are shown in Figure 4a & 4b and 5a & 5b.

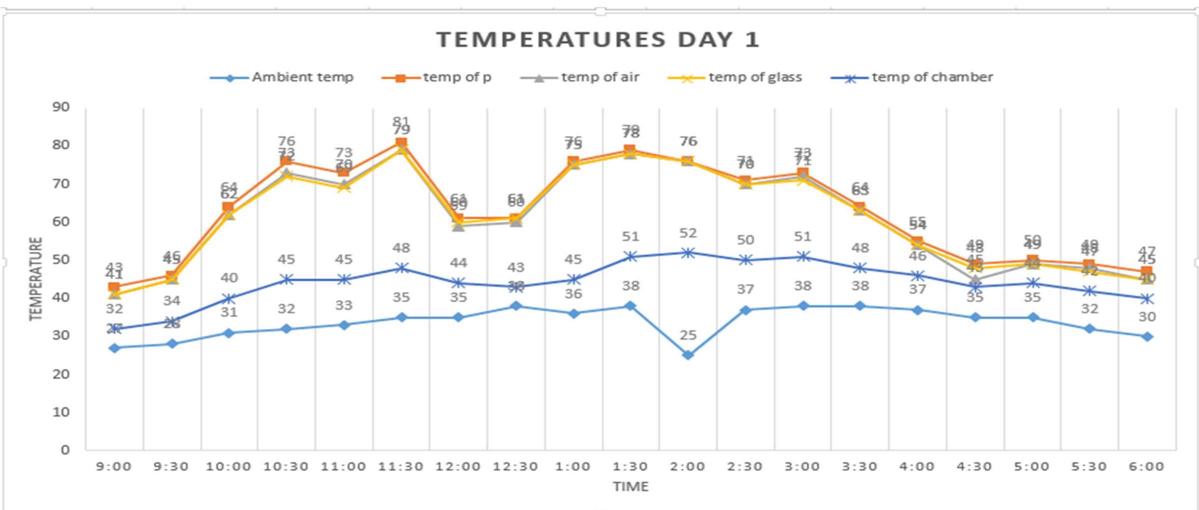

Figure 3a: A graph of temperature against time (day 1).

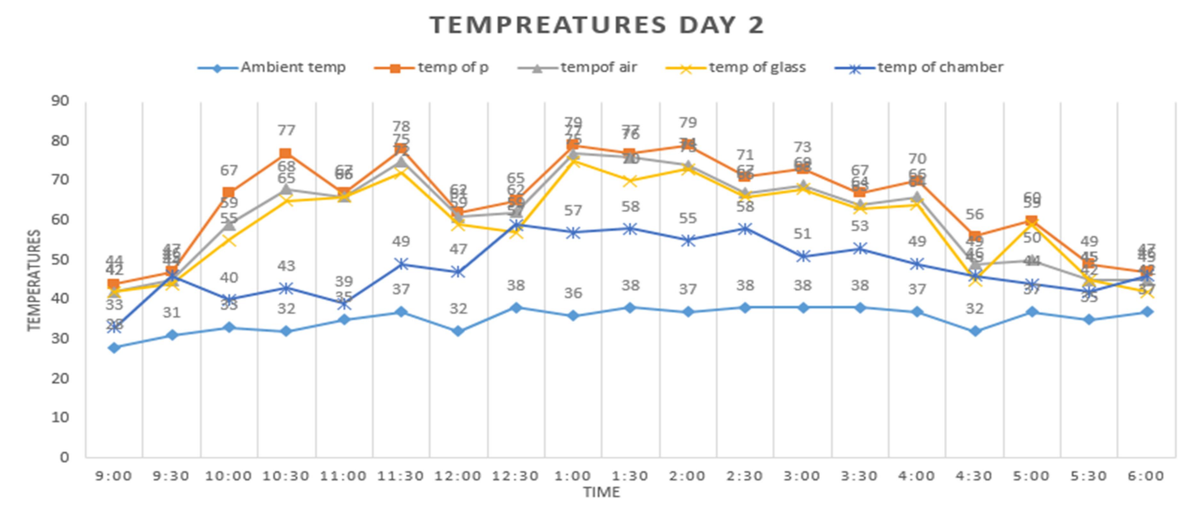

Figure 3b: A graph of temperature against time (day 2).

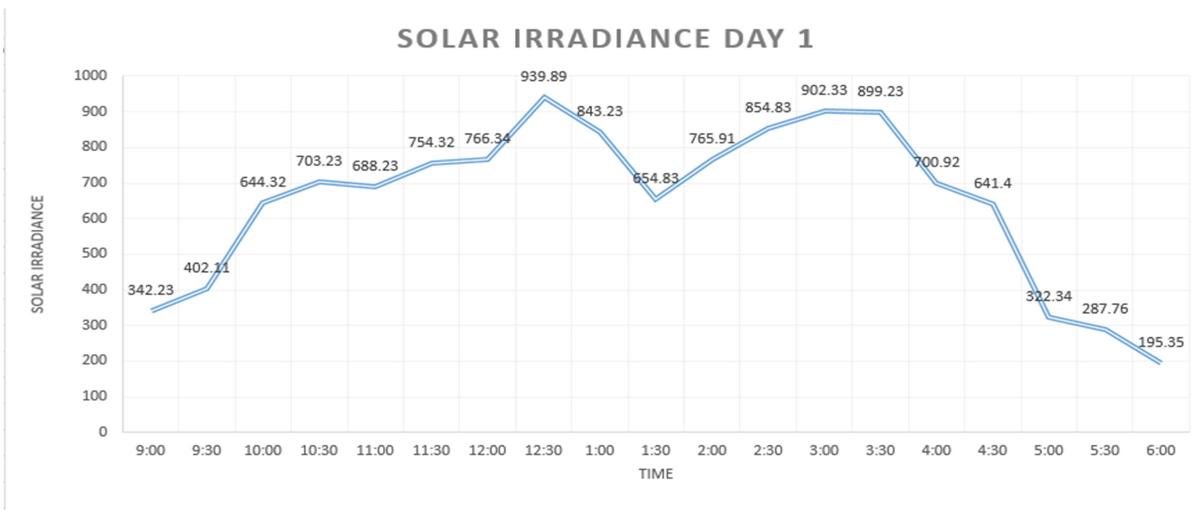

Figure 4a: A graph of solar irradiance against time (day 1).

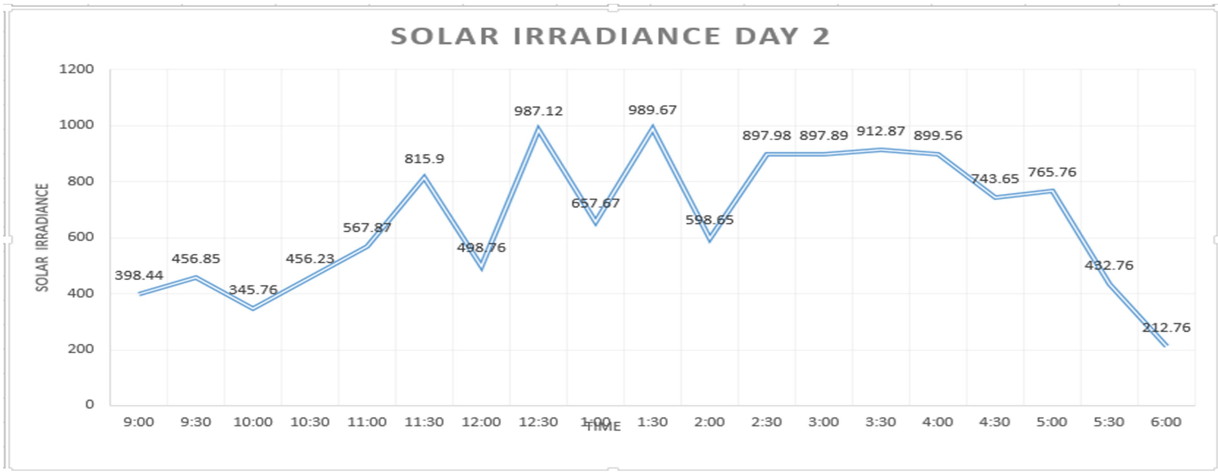

Figure 4b: A graph of solar irradiance against time (day 2).

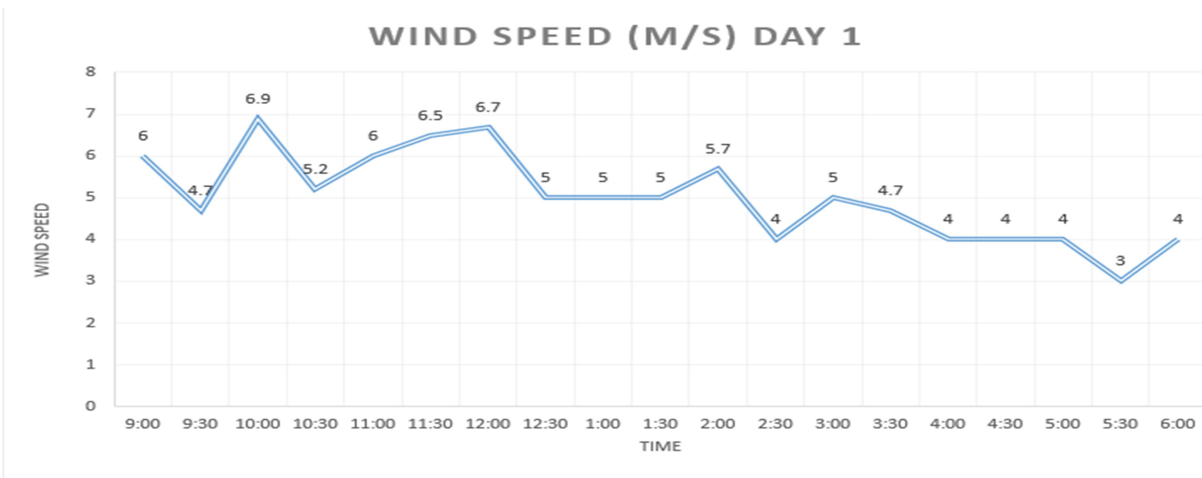

Figure 5a: A graph of wind speed against time (day 1).

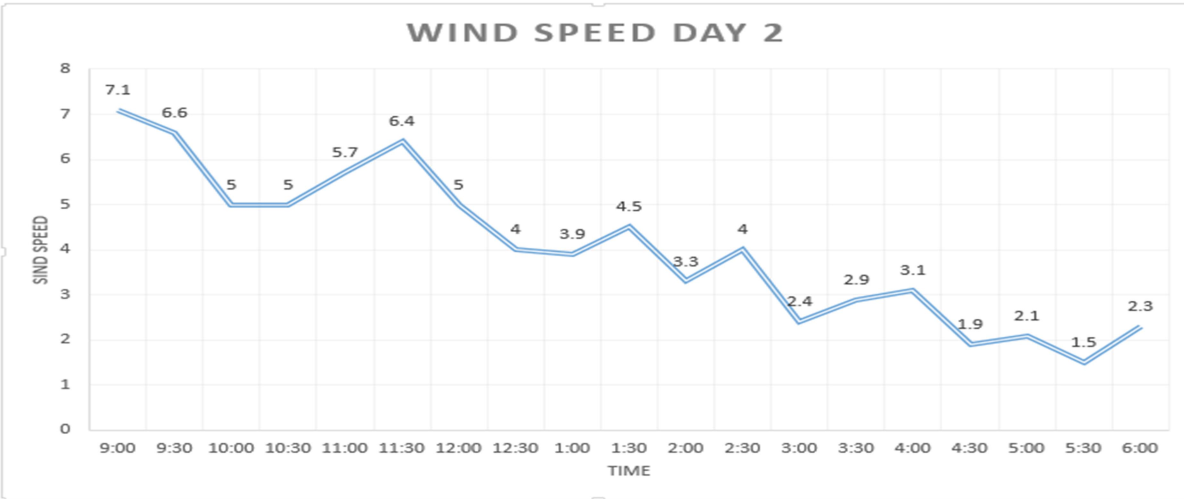

Figure 5b: A graph of wind speed against time (day 2).

CONCLUSION

An indirect solar dryer was constructed and was studied under actual environmental conditions of Sokoto, Sokoto State of Nigeria. It is an economical means to providing long term food preservation for remote areas and small communities in arid zones. Appropriate materials were chosen for constructing the various components of the solar dryer. From the tests carried out, the following conclusions were made.

The solar dryer can raise the ambient air temperature to a considerable high value for increasing the drying rate of agricultural crops. The product inside the dryer requires less attentions, there is ease in monitoring when compared to the natural sun drying technique. The capital cost involved in the construction of a solar dryer is much lower to that of a mechanical dryer.

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