Investigating the Effect of Rock Bed Storage Performance on Solar Dryers

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Abstract— This paper is to investigate the rock bed storage effect on the performance of solar dryers. The solar drying system uses solar radiation to dry agricultural product put on it. From the test carried out it's revealed that the dryer with storage material can perform more efficiently than those without storage. The Indian standard method of testing solar thermal was adopted. From the result it was observed that the highest grave temperature to be 690C and the solar radiation was 947.1W/m2. For further research candle wax should be use which can also fasten the rate of drying agricultural product and also investigate the performance of the solar dryers.

Key words: Solar Dryers, Rock Bed Storage

I. Introduction

Agricultural products are of great nutritional and health importance since they make significant contribution in supplying essential vitamins, minerals, antioxidants, fibers and carbohydrates that improve the quality of the diet and also contain constituents that have health benefits and anti-disease factors, such as antioxidants and polyphenols. These components are known to scavenge harmful free radicals that are associated with incidence of cancer and heart diseases (Cao et al., 1996; Velioglu et al., 1998). Unfortunately, fresh fruits and vegetables are not only seasonal but highly perishable since the moisture content is more than 80%, they are classified as highly perishable commodities (Orsat et al., 2006). As a result they Detroit very fast few days after harvesting, losing almost all their required quality attributes and some could likely result to total waste.

II. Materials & Method

A. Materials Used for the Solar Dryer Construction

The following materials will be use for the construction of a direct combine solar dryer:

1) Galvanized Sheet

Will be use as the casing (housing) of some parts of the chamber (side and back of the drying chamber). A 0.9mm thickness of the galvanized sheet was also used for the absorber plate.

2) Glass

Will be use as the solar collector cover, the drying chamber and for the roofing. It Permits the solar radiation into the system but reduces the flow of heat energy out of the Systems

- Galvanized iron frames for the drying trays.
- Nails and glue as fasteners and adhesives.
- Insect net at air inlet and outlet - to prevent insects from entering into the dryer.
- Hinges and handle for the dryer's door.
- Paint (black) and top gum
- Pyranometer is used to measure solar radiation
- Anemometer is used in measuring wind speed
- Weighing balance is used to weigh the weight of a substance
- Also, a thermometer was used to measure the ambient and dryer temperature and
- Wood is also use for the assembling of the entire dryer

III. Tomato Samples

In this study, tomato was chosen as the product to be dried because of its limited shelf life at ambient conditions and its high perishes ability. Good quality fruits were purchased from a local fruit market of birnin kebbi. Tomatoes were washed with water to remove skin dirt, cut into slices of 1 cm thickness. Seeds were removed and the slices obtained were uniformly laid out on the trays of the direct solar dryer (Liberty, (2014).

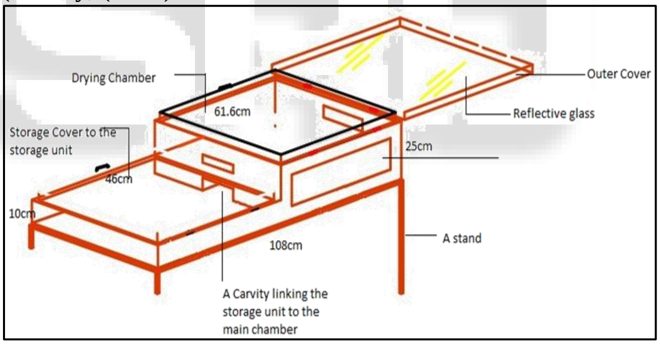

Fig. 1: Showing Design of the Solar Dryer

IV. Properties of Materials

GLASS	SPECIFICATIONS
Reflector	1
Thickness	4mm
Emittance	0.92-0.94
Length and breadth	64cm by 64cm
ABSORBER PLATE	
Inner plate	Galvanized sheet
Thickness	0.9mm
Color	Ash
Thermal conductivity	19W/mk
ROCK BED	
Thermal conductivity	1.8W/mk
Specific heat capacity	0.92jkg

Table 1:

V. DATA COLLECTION

The India standard based on thermal test for solar dryer, the method highlighted two methods of test firstly stagnation test (test without storage) and secondly the storage test (Ayoola et al., 2014). The temperatures were measured by using thermometer and solar radiation was measured using pyranometer and also weighing balance was used to measure the weight of the tomatoes every one hour of the day. The wind speed is also measured by using the digital Anemometer, The test on solar dryer was done on the month of October 2017. As the experiment started around 8:00am and end 6:00pm, every 20 minutes data was collected and recorded further more average hourly data was also computed.

VI. THE SYSTEM DRYING EFFICIENCY

The system drying efficiency (η_d) is the amount of heat required to evaporate the moisture inside the product and is computed from (Ezekoye and Enebe, 2006)

$$\eta_d = \frac{\text{heat output}}{\text{heat input for a given time}} \quad 1.1$$

$$\eta_d = \frac{ML_V}{I_C A_C t} \times 100 \quad 1.2$$

Where M is the amount of moisture evaporated (ML) (Kg/hr) I_C is the totally hourly insulation on the collector, A_c is the area of collector (M^2), t is the drying time, L_V is the latent heat of vapourirazation of water (2320kj/kg).

VII. DATA EVALUATION

The evaluation of the solar dryer involves estimation of the following parameters Firstly the calculation of the moisture content and also to determine the efficiency of the system

$$\%\ \text{moisture} = \frac{A-B}{A} \times 100 \quad 1.3$$

Where:
A = Original weight of sample
B = Weight of dried sample.
Evaluating the efficiency of the system can be obtained with the equation below.

$$\eta_d = \frac{\text{heat output}}{\text{heat input for a given time}}$$

$$\eta_d = \frac{ML_V}{I_C A_C t} \times 100 \quad 1.4$$

Where M is the amount of moisture evaporated (ML) (Kg/hr) I_C is the totally hourly insolation on the collector, A_c is the area of collector (M^2), t is the drying time, L_V is the latent heat of vapourirazation of water (2320kj/kg).

VIII. PERFORMANCE EVALUATION

First we determine the moisture content of the tomatoes and also the efficiency of the sys:

$$\%\ \text{moisture} = \frac{A-B}{A} \times 100$$

Where:
A = Original weight of sample
B = Weight of dried sample.
A=0.90 and B=0.67
From the equation (3) above we can substitute the values into the equation
% moisture =0.90-0.67/0.90 =0.25x100 =25%
The overall efficiency of the system is given as

$$\eta_d = \frac{\text{heat output}}{\text{heat input for a given time}}$$

$$\eta_d = \frac{ML_V}{I_C A_C t} \times 100$$

M =0.23kg, L_v =2320kj/kg, $I_{c,}$ =989.1W/ m^2,A_c=0.64m^2 t =18000s.
Put these values into the equation (4) above. So therefore η_d = 4.6

IX. RESULTS

The results of the variation of solar radiation, grave temperature and temperature of the chamber as shown in Figure 1.1. Where the primary vertical axis shows the hourly average value of solar radiation and secondary vertical axis shows a similar result but for temperatures. The Figure reveals that the solar radiation and temperatures began to increase from 8:00 am, reaching a peak value of about 947.1W/m^2, 49^{0}C around 12:00 noon, the temperature reach a peak value of 67^{0}C and 69^{0}C. Further observation from the Figure shows that a decrease in solar radiation from around 2:00pm to 6:00 pm. However, the temperature decrease with respect to time

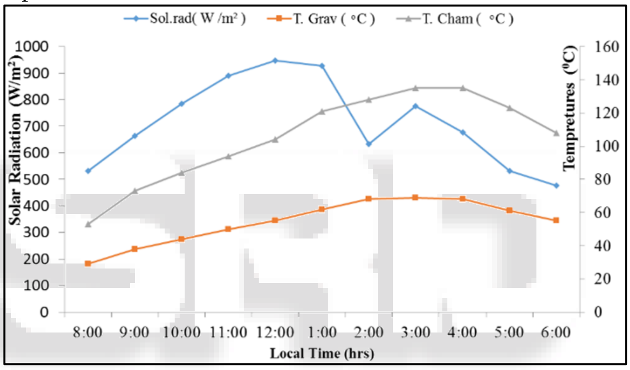

Fig. 1.1: The Drying System

The result of the variation of wind speed and the ambient temperature as shown in Figure 1.2 Where the primary vertical axis shows the hourly average values of wind speed while the secondary vertical axis shows a similar result but for ambient temperature. The figure reveals that the wind speed shows periodic rise and fall while the ambient temperature at around 8:00 am was at its peak value of 41(^{0}c) and fall. Further observation from the plot reveals that around 11:00 am to 400: pm the ambient temperature maintained a steady state of 40 (^{0}c) with still a periodic rise and fall of wind speeds at 5:00 pm the ambient temperature drop with increase in wind speed. This shows an inverse relationship of the two parameters at a certain interval.

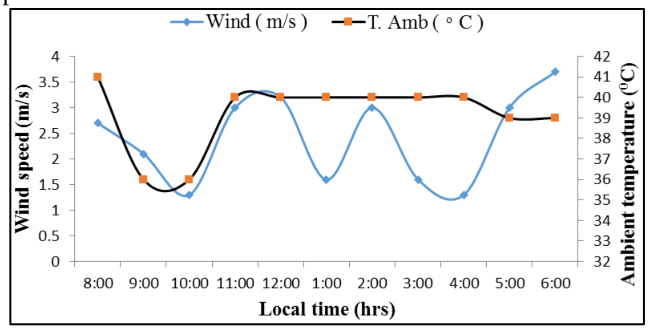

Fig. 1.2: Wind Speed & Ambient Temperature

The results of the variation of solar radiation and grave temperature as shown in Figure 1.3 Where the primary vertical axis shows the hourly average value of solar radiation and secondary vertical axis shows a similar result but for temperatures. The Figure reveals that the solar radiation and temperatures began to increase from 8:00 am, reaching a peak value of about 947.1W/m^2 around 12:00noon and 69^{0}C at about 3:00pm. Further observation from the Figure shows that a decrease in solar radiation from around 1:00pm to 6:00pm. However the temperature of the grave decrease with respect to time.

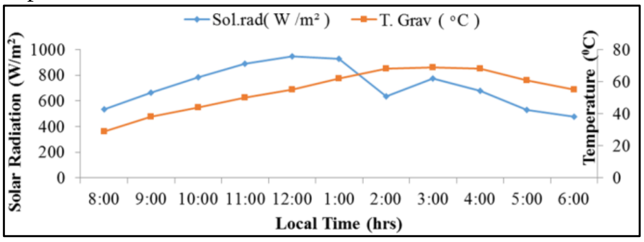

Fig. 1.3: Solar Radiation & Temperature

The results of the variation of drying chamber and grave temperature as shown in Figure 1.4 where the primary vertical axis shows the hourly average value of drying chamber and secondary vertical axis shows a similar result but for grave temperature. The figure reveals that the drying chamber and grave temperature began to increase from 8:00 am reaching a peak value of about 67^{0}C around 4:00pm and grave temperature was 69^{0}C at about 3:00pm. Further observation from the Figure shows that a decrease in drying chamber and grave temperature was consistent with respect to time which actually shows that the substance is drying fast because of the grave as the thermal storage. This shows that there is a relationship between the parameters in a particular time.

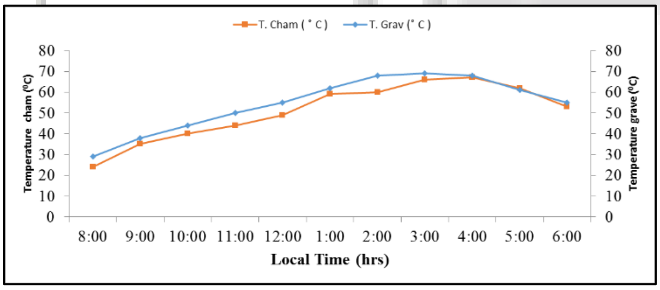

Fig. 1.4: Drying Chamber & Grave Temperature

X. DISCUSSION

In this study, a solar dryer was constructed and used to dry tomatoes. The performance of the dryer was tested based on the relationship between the solar radiation, grave temperature, ambient temperature and wind speed of the dryer was also computed. The result from this study reveals that solar radiation, temperatures, ambient temperature and wind speed increased with time from 8:00 am to 4:00 pm because of the sky is clear while the wind speed fluctuate because of the solar radiation reduced and started fluctuating from the system, however, the temperatures decrease as solar radiation decreased because of cloud cover when the ambient temperature maintained a peak value because the effect of wind speed to the system. This discussion was from Figure 1.1 to 1.4.

XI. CONCLUSION

From the test carried out the following conclusions were made. The solar dryer with rock bed as thermal storage can raise the highest temperature of the drying chamber more than an ordinary dryer to a considerable high value for increasing the drying rate of agricultural crops. The capital cost involved in the construction of a solar dryer with storage facilities is almost the same with the one without storage facilities and much lower to that of a mechanical dryer and also from the test carried out the simple and inexpensive of this dryer was constructed using locally sourced materials.

XII. RECOMMENDATION

Although limitation was encountered during the execution of this research but it gives room for further research.

1) To use aluminum sheet in constructions of solar dryer instead of galvanized sheet to compare the two materials.
2) Further tests should also be carried out during more sunny days or periods of the year.
3) More alternative material for thermal storage should be investigated to come up with one that can give the most optimal system performance.

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