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Fabrication and characterization of a direct absorption solar dryer

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ABSTRACT

Based on preliminary investigations under controlled conditions of drying experiments, a direct absorption solar dryer was fabricated from local materials and tested under actual environmental conditions of Obinugwu, a popular community in Orlu, Imo State, Nigeria. This paper describes the fabrication techniques and presents the results of diurnal temperature variation between the hot box and the surrounding. The dryer was fabricated with a hot box of area 0.39 m^2. A glass roof was designed to rest onto the hot box which also served as the drying chamber. The average of the ambient temperatures recorded was 33^0C, whereas 59^0C was the average temperature of the drying chamber. Temperature measurement was carried out within nine consecutive days.

Keywords: Solar dryer, Nigeria, agricultural products, glass roof.

INTRODUCTION

One of the most common methods of preservation is drying, which reduces water activity through the decrease of water content, thus preventing deterioration and contamination during long storage [1-6]. Drying causes physical and chemical stability with reduction in weight, volume and transportation costs [1,7-9]. Also, food quality is preserved, the hygienic conditions are improved and products loss is diminished [7,8]. For these reasons, several methods or combination of dehydration process can be used, including solar drying, hot-air, freeze drying, osmotic dehydration, spray drying, impregnation vacuum and so on [1].

Drying operations involve both heat and mass transfers. Drying is an important time and energy consuming process. Product size, density, moisture content, drying air temperature, relative humidity and air velocity [10] are some of the major parameters affecting the drying time and dried product quality. Ascorbic acid content of the product is one indicator of the potential preservation of nutrients [8,11] and would change with processing, conditions of the drying air, light, heat and drying time.

Food drying is a very simple, ancient skill. It is one of the most accessible and hence the most widespread processing technology. Dryers have been developed and used to dry agricultural products in order to improve market value and shelf life [12]. Most of these either use an expensive source of energy such as electricity [13] or a combination of solar energy and some other forms of energy [14,15]. Most projects of this nature have not been adopted by the small farmers, either because the final design and data collection procedures are frequently inappropriate or the cost has remained unaffordable and the subsequent transfer of the technology from the researcher to the end user has been anything but ineffective [16].

Open-air and uncontrolled sun drying is still the most common method used to preserve and process agricultural products in most tropical and subtropical countries [2,12,17,18]. The main advantages of sun drying are low capital and operating costs and the fact that little expertise is required. The main disadvantages of open-air sun drying are as follows: contamination, theft or damage by birds, rats or insects; slow or intermittent drying and no protection from rain or dew that wets the product [1,12]. Ultra violet radiation in the sun rays may cause deterioration of active ingredients and also affect the texture, colour and flavor of the product. Hence, products may be seriously degraded to the extent that sometimes they become market valueless and inedible and the resulted loss of food quality in the dried products may have adverse economic effects on domestic and international markets.

Solar drying in a closed environment such as in a drying chamber would reduce the risk of environmental damage and provide a better control over the drying parameters. Hence, it is absolutely imperative to design a simple solar dryer. Solar dryers may be classified according to the mode of air flow as natural convection and forced convection dryers [19]. Natural convection dryers do not require a fan to blow air through the dryer. Solar drying may also be classified into direct absorption dryers, indirect and mixed-modes [19,20]. In direct solar dryers the air heater contains the materials and solar energy passes through a transparent cover and is absorbed by the materials. Essentially, the heat required for drying is provided by radiation to the upper layers and subsequent conduction into the material bed. In indirect dryers, solar energy is collected in a separate solar collector (air heater) and the heated air then passes through the material bed, while in the mixed-mode type of dryer, the heated air from a separate solar collector is passed through a material bed and at the same time, the drying cabinet or chamber absorbs solar energy directly through the transparent walls or roof.

In this research work, we fabricated a very simple direct absorption solar dryer (DASD) from local materials. The main features of the DASD are the hot box, glass roof, sliding door and other ventilation holes. The hot box is actually the drying chamber.

MATERIALS AND METHODS

The main features of the direct solar absorption dryer include; a rectangular wooden box with blackened interior, ventilation holes in the base and upper parts of the side walls, and a transparent glass roof sitting on top of the rectangular hot box. The drying chamber was fabricated with a 2.5 cm thick soft wood and has a total surface area of 0.39 m^2. The drying bed was made up of three different layers:

(i) A thin layer of foam which was used to cover the inner surface of the rectangular wooden box,
(ii) Aluminium sheet which was used to cover the foam,
(iii) Finally, a black leather was used to cover the aluminium sheet.

Incident solar radiation passes through the transparent glass roof and falls on the black absorber surface. The aluminium sheet is a good conductor of thermal energy while the foam helps to retain the heat so far generated. The wooden material used to fabricate the box is a good insulator of heat, hence; heat entrapped in the drying chamber is retained thereby ensuring high temperatures even for hours after sunset.

Figure 1 shows the hot box with a 5 cm diameter outlet. This outlet is necessary for the discharge of hot air and vapour from the drying chamber. Figure 2 shows the hot box with the glass roof in place. The small opening (Inlet 1) is an inlet for fresh air. Experimental tools, like the thermometer can also be inserted through this hole. Another inlet for fresh air (measuring 10 x 6 cm) is shown in Figure 3 with a sliding door fastened to it. This opening is also an avenue for deposition or removal of materials from the drying chamber. The sliding door also enables adjustment of the inlet for fresh air.

The ambient temperature (external temperature) was recorded hourly during the day for nine consecutive days (3rd April, 2012 to 11th April, 2012). The corresponding temperature of the hot box (internal temperature) was also measured. Temperature measurement was carried out using a copper/constantan thermocouple under actual environmental conditions of Obinugwu, an ancient community in the Eastern part of Nigeria.

Figure 1. The hot box

Figure 2. Direct Absorption Solar Dryer (DASD)

Figure 3. Direct Absorption Solar Dryer (DASD) showing the sliding door

RESULTS AND DISCUSSION

Hourly variation of ambient temperatures with temperatures of the hot box for the nine days is shown below (Fig. 4 – Fig. 12). Temperature values for the surrounding and the hot box were almost the same at dawn but as incident solar radiation increases, the temperature of the hot box increases with a very high margin. The highest value of internal temperature recorded was 90^0C when the temperature of the surrounding was 35^0C.

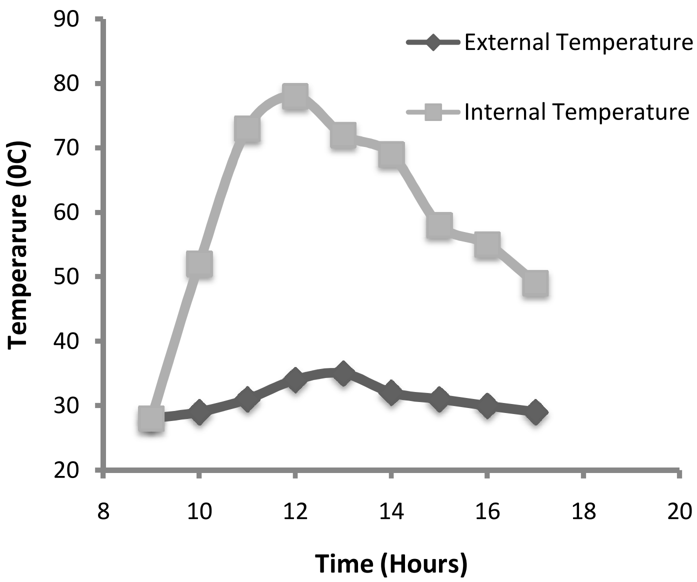

Figure 4. Temperature-Time curves for Day1

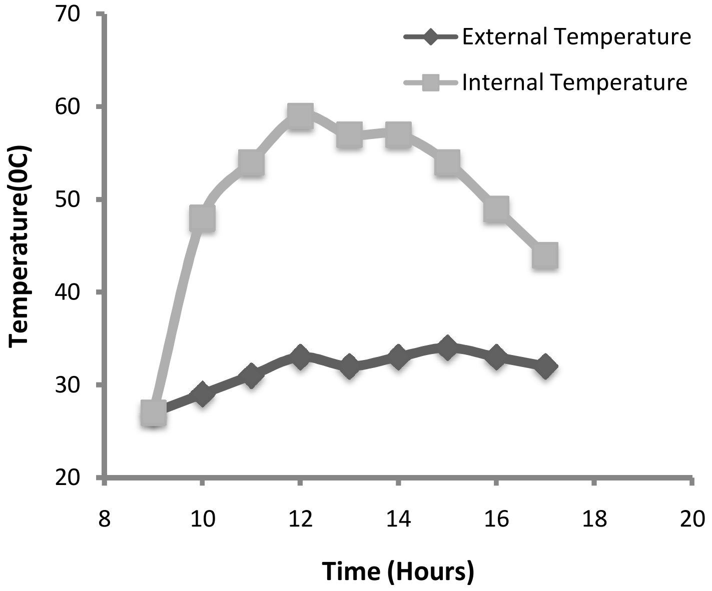

Figure 5. Temperature-Time curves for Day 2

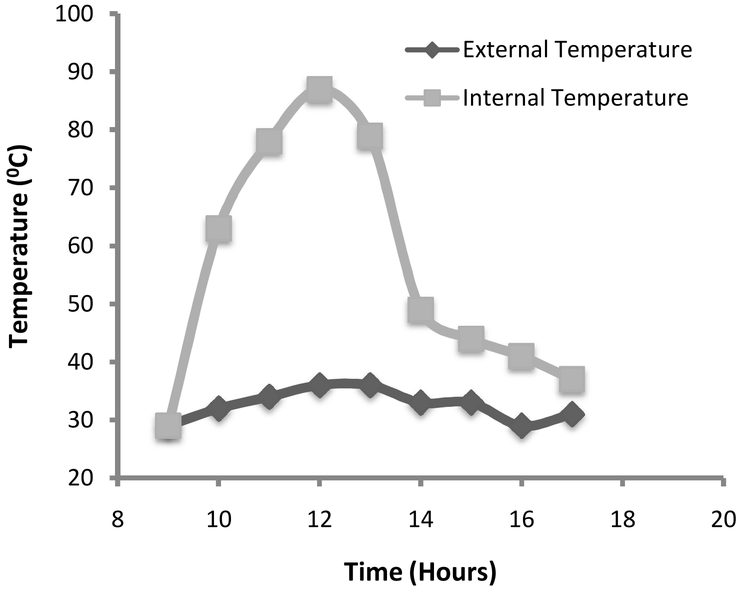

Figure 6. Temperature-Time Curves for Day 3

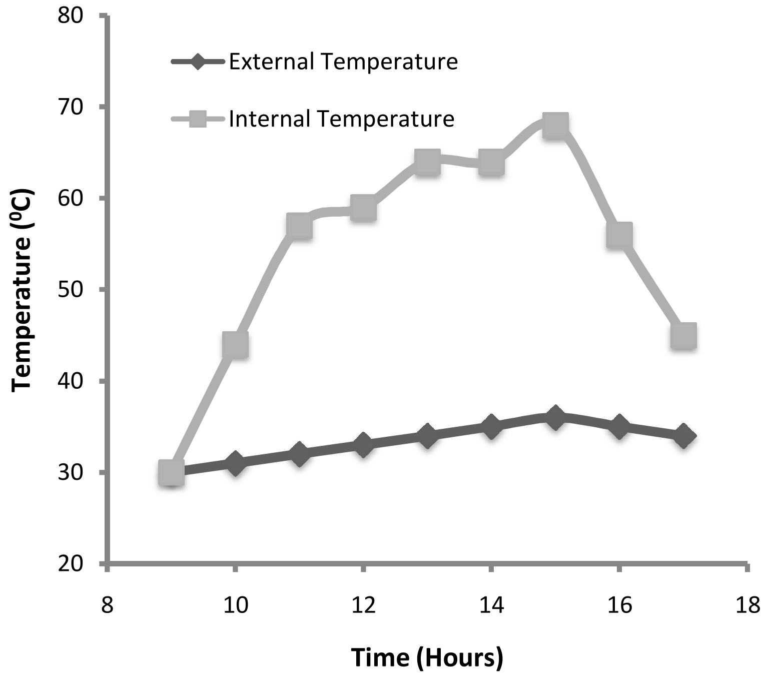

Figure 7. Temperature-Time curves for Day 4

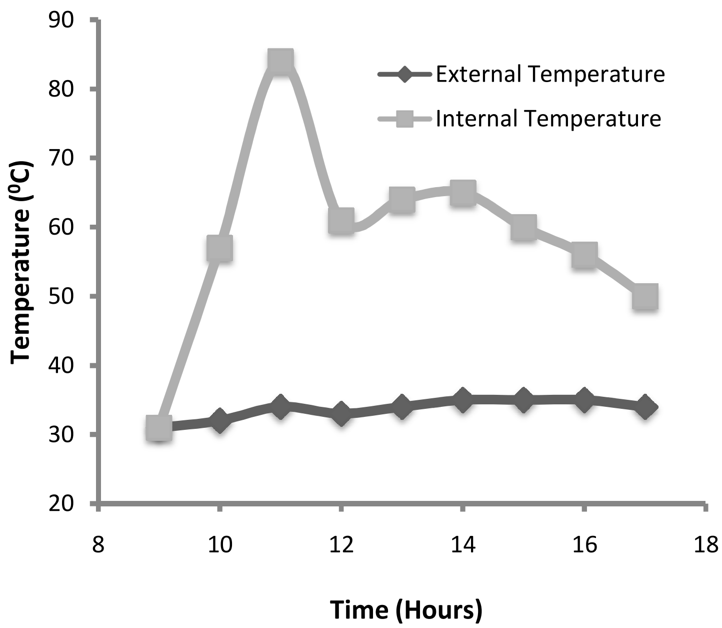

Figure 8. Temperature-Time curves for Day 5

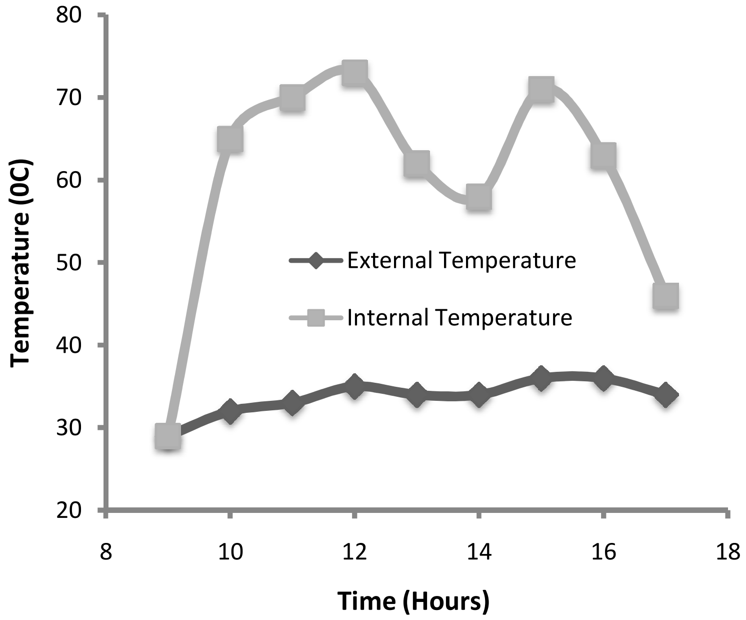

Figure 9. Temperature-Time curves for Day 6

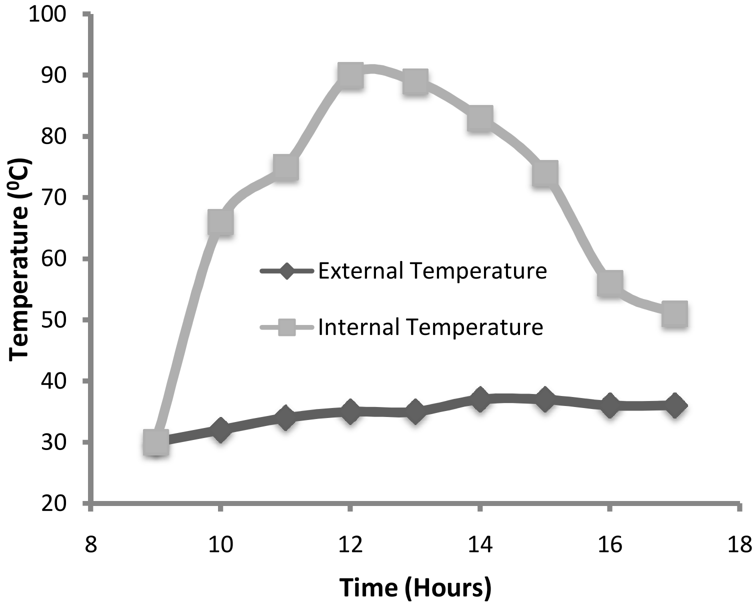

Figure 10. Temperature-Time curves for Day 7

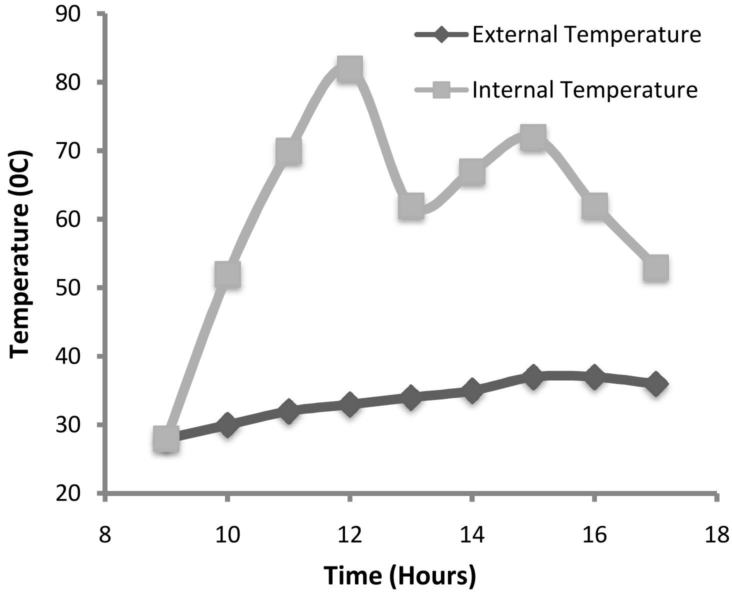

Figure 11. Temperature -Time curves for Day 8

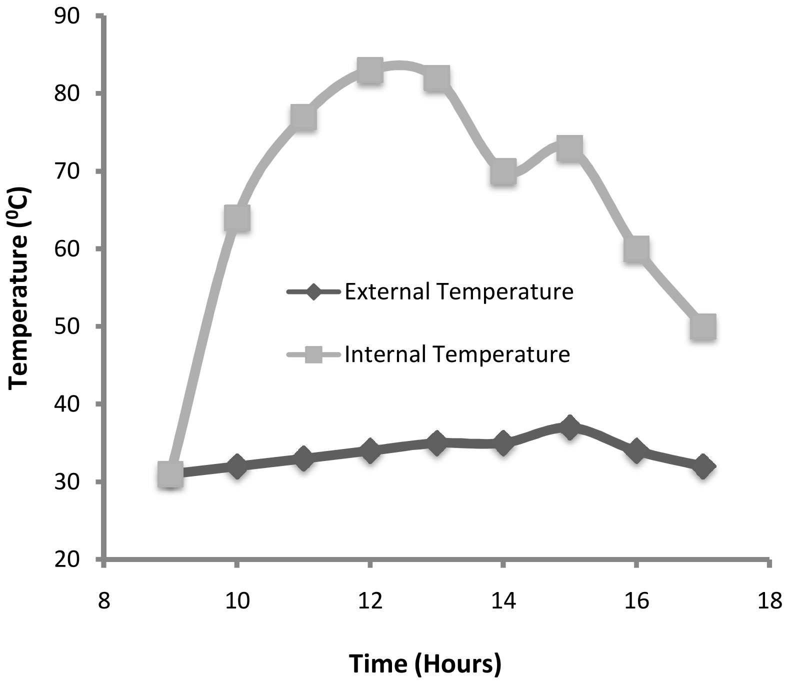

Figure 12. Temperature-Time curves for Day 9

Table1 shows the daily maximum temperature variation; where T_{df} is the difference between internal and external temperature. The average of the temperatures recorded per day is shown in Table 2; where T_{av_ex} is the average of the hourly atmospheric temperature and T_{av_in} represents the average of the hourly internal temperature.

Table 1. Daily Maximum Temperature Variation

Day	01	02	03	04	05	06	07	08	09
$T_{df}(^0C)$	44	26	51	32	50	38	55	49	49
Time	12noon	12noon	12noon	3pm	11am	12noon	12noon	12noon	12noon

Table 2. Daily Average Temperature

Day	01	02	03	04	05	06	07	08	09
$T_{av\_ex}(^0C)$	31.00	31.56	32.56	33.33	33.67	33.67	34.67	33.56	33.67
$T_{av\_in}(^0C)$	59.33	49.89	56.33	54.11	58.67	59.67	68.22	60.89	65.56

CONCLUSION

A low cost direct absorption solar dryer was fabricated and the drying chamber was able to generate hot air of very high temperatures. The margin between the internal and external temperatures was as high as 55^0C. The device is easy to operate and maintain, and the components are locally available. The DASD has the potential for application in drying various agricultural products, and will eliminate most of the problems associated with open air sun drying. One can fabricate many DASDs to meet up with daily demand since the dryer is environment friendly and has low operating and maintenance costs. Also, drying of products on large scale can be achieved by fabricating a DASD of very large surface area. Ultra violet stabilized polythene sheet could be used to protect the glass roof in order to prevent the adverse effects of UV radiation on agricultural products.

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