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Design and construction of fruit solar drier for rural settlements

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Abstract

This research focuses on the need for preserving fruits in rural areas to prevent waste. The solar drier is made of vital chambers i.e. the concentrator chamber (that harvests the solar irradiance), the transport pipe (that transports the heat generated by convection) and hanger chamber (where the fruits are placed). The temperature within the concentrator chamber and hanger chamber was monitored. The design allowed heat transfer by convection from the collector to the chamber at an efficiency of 92 %. The design allowed the temperature build up in the solar collector to be transported faster through hanger chamber with the help of incorporated detachable low power dc fan. This arrangement makes the dryer to either operate in the natural convection dryer mode (without the fan) or as a forced convection dryer (with the fan attached). It is observed that the forced convection provided higher air in-flow and hence greater drying capability. However, regions with moderate precipitation may have challenges of delayed fruit drying and growth of microorganism over the surfaces of the dried fruit.

1. Introduction

In 2000, the United Nations Development Program reported that the yearly solar energy potential in the globe was about 1,575–49,837 exajoules (EJ) which is greater than the global energy consumption that was 559.8EJ in the year 2012 [1]. The research done by the United Nations and other scientist indicates that the use of solar power in the world will be enough for every consumer of energy and it is a relatively cheap, inexhaustible and clean source of energy [2-9]. In recent time, there are two major techniques used in harnessing solar energy that are currently in use, they include; solar photovoltaic and solar thermal processes [3,4,10-14]. Sunlight based warm advancement is a development that is rapidly grabbing affirmation as an essentialness saving measure in agriculture usage. It is wanted to other elective wellsprings of vitality, for example, wind and shale, since it is rich, endless, and non-dirtying. Sun-based air radiators are devices that are constructed to warm air for numerous applications that cut across domestic to industrial usages [5].

Solar application has moved unto thermal application that can be harnessed for two distinct applications, i.e. generation of electricity (using steam mechanical engines) and providing warm fluids used for household applications [8, 15].

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One of the vital components in solar thermal technology is the solar collector. The most common solar collector is the parabolic trough system. The basic components of a parabolic trough system include the receiver tubes; curved mirror assemblies (concentrators) and the heat transfer fluid (HTF) [9]. The receiver is the component that transforms solar energy to thermal energy in the form of latent heat of the fluid that circulates through it [9]. The absorber is an important part of a solar power plant that has significant influence on its performances. The absorber is usually made of a transparent material such as elastic or glass, however electro-chemically deposited black chrome is widely used because of its capability to resist high temperatures [2]. Various sorts of sun-powered dryers have been planned, created and tried in various areas of the tropics and subtropics. The real two classes of the dryers are common convection sun-based dryers and constrained convection sunlight-based dryers. In the regular convection sun oriented dryers the wind current is built up by lightness incited wind stream while in constrained convection sun-based dryers the wind current is given by utilizing fan worked either by power/sun oriented module or petroleum product. Traditional sun-oriented drying is different from sun drying device. Sun drying is a typical method adopted in rural communities of developing countries - especially where the open-air temperature achieves 30ºC or higher. Sunlight-based device has been utilized all through the world to dry items. The same principles replicated in sun-oriented dryers. Material that are dried using solar-based device includes grains, organic products, meat, vegetables and fish [5]. Drying forms assume a significant job in the conservation of horticultural items. They are characterized as a procedure of dampness expulsion because of synchronous warmth and mass exchange [7]. The main agricultural produced under the category of fruits and vegetables are citrus, pineapple, banana, pawpaw, cashew, mango, tomato, okro, pepper, and onion [16]. [16] stated that although agriculture is the largest sector of the economy in Ghana, contributing about 39% of GDP, there are basic problems faced by this sector which include high post-harvest losses as a result of poor post-harvest management. For instance, Ref [17] has given an estimate showing that the average post-harvest loss of mango is between 40% and 70%. The main reason for losses has been credited to the organic product fly nearness and a large group of ailments just as the absence of virus chain offices, and long travel time [1]. The researcher also suggested that there would be loss of fresh produce during the harvest period because of excess production that could lead to unsold produce. This surplus produce should be stored so that it can be used later. But it might be unsafe to keep these produce over a long period due to high moisture content, physical damage, pathogens etc. The motivation behind solar drier projects is to exhibit the improvements and possibilities of sun-powered drying advancements for drying grains, organic products, vegetables, flavors, and restorative plants. So as to lessen such postharvest misfortunes to empower ranchers increment the nature of their items, effective and moderate drying techniques are fundamental. Sun- powered dryers can be regarded as one of the methods for reducing agricultural losses [18]. Since real knowledge is in the application of information received, it is worthy of note that several researchers have been able to harness this knowledge in practical use and designing of solar dryers. According to [19], a Double-Pass Solar Dryer (DPSD) for drying of red chili was designed and the performance efficiency was compared with the Cabinet Dryer (CD) with respect to the open air-drying. The DPSD, which is classified as forced convection was found to be more efficient, but with a higher design cost. Further studies shown by [20] presented an environmentally friendly, indirect, and low-cost solar dryer for drying a variety of agricultural products like banana. Result from the design shows that as much as 60W of energy can be conserved for the same amount of input energy compared with a non-forced convection dryer. Research [21] classified solar dryers broadly as active solar-energy drying system and passive solar-energy drying system, further stressing the fact that active solar-energy drying systems are hybrid solar dryers while the passive ones are natural-circulation solar drying systems.

According to [22], mix-mode solar dryer was identified. It is a natural convection dryer suitable for drying agricultural produce because of its capability to attain required moisture level within a desired time frame thereby reducing the loss of agricultural products. [23] in its review was able to identify different types of solar dryers, some of which include: open sun drying, direct solar dryer, indirect solar dryer etc. In its own submission, Ref [24] identified hybrid solar dryer that comes in different varieties.

In this study, the solar fruit drier is designed according to the above prescription. This device is very important in rural areas to preserve fruits by drying. The success of this system depends on the annual solar irradiation over the given geographical region.

2. Design objectives

The main objective of this project is to design a device that uses solar energy to dry fruits. This device must be portable, self-contained, and rugged enough to withstand equatorial climates. The device must be easy to assemble, disassemble, and use. The device must be low cost so that farmers in developing countries, or a government organization that distributes it among the citizens can purchase it.

3. Mathematical methods

The common design types are of bureau structure (wooden boxes with glass spread), a few sorts are even altered utilizing cardboard boxes and non-reflecting nylon or polythene. For the structure being considered, the nursery impact and thermo siphon standards are the hypothetical premise. There is an air vent (or channel) to the sun powered gatherer where air heads inside and is warmed up by the nursery impact, the sight-seeing rises through the drying load experiencing the plate and around the nourishment, expelling all dampness substance and exits through the fumes fan at the highest point of cupboard. The organic product sunlight based drier comprises of two noteworthy compartment or chambers being coordinated together:

1. The sun is the main source for operating certain solar-based device such as air radiator framework.
2. The drying chamber, intended to oblige four layers of drying plate made of net (cheddar material) on which the items (or natural product) are set for drying [25].

The accompanying materials were utilized for the development of the residential organic product sun powered dryer. Plywood was chosen for the whole packaging, since it is light in weight, effectively accessible and less expensive in expense in comparison to other materials. Glass was used for the upper covering of the air warmer chamber since it effectively permits the beams to infiltrate through the sheet and it opposes the warmth from getting away. Aluminum thick sheet of 3mm thickness was used to expand the temperature of air going through the air chamber painted dark with tar for the absorption of sun oriented radiation. The net utilized for building the plate for putting the item in the drying chamber. Nails, 5mm screws and nuts paste and silicon stick were used as latches and glues. Rubber pipe of 10cm width was used to connect both chambers. Low pore-sized net at air channel and outlet was used to confine the creepy crawly to enter inside the chamber.

4. Design consideration

1. The base temperature for drying organic product is 25°C and the maximum temperature is 55°C. In this research, the plan was made for an ideal temperature for the drier. $T0$ of 65°C and the air delta temperature or the surrounding temperature of dryer was $T1 = 35$°C (around outside temperature).
2. The efficiency is characterized by estimating the temperature in two chambers of the solar drier.
3. Air hole connecting the chambers is recommended for hot atmosphere latent sun powered dryers, a hole of 10 cm ought to be made as air vent (channel) and air entry.
4. Glass and level plate sun powered gatherer were used so that the glass covering ought to be 4-5mm thickness. In this work, 5mm thick straightforward glass was utilized. It additionally recommended that the metal sheet thickness be

of 0.7 – 1.2mm thickness; here the aluminum of 1.0mm thickness was utilized.

5. The dimension is such that a consistent trade of air and a large drying chamber ought to be accomplished in sun based nourishment dryer structure, in this way the plan of the drying chamber was made as extensive as conceivable of normal element of 50 ×47 ×45cm with air section (air vent) out of the bureau of 50 ×5cm2.

6. Drier trays was chosen as the dryer screen or plate to help air flow inside the drying chamber. Three plates were made of metal net. The plate measurement is 48 × 48cm.

7. Exhaust aficionado of 12v is utilized to expel the air from the drying chamber. The plan of the dry chamber utilizing wooden divider sides and a top shields the organic products from direct daylight.

The solar drier is designed to have five compartments namely, (a) air inlet opening attached with detachable fans, ventilation compartment (comprising the fan), (b) solar collector or concentrator chamber (c) heat transport pipe (d) hanger or drying chamber and (e) exit pipe (Fig. 1).

The design of the solar dryer provides the opportunity for it to be used in either the natural convective drying mode or the forced convective drying mode. The forced convective mode that gives quicker drying process uses an external direct correct fan powered by a small monocrystalline solar panel (Fig. 2). This is aimed at providing the necessary power to drive the fan hence increasing the air inlet. In addition, for better efficiency, a 12V 7AH battery keeps the fan running for optimum ventilation when there is cloud cover in order to reduce moisture deposit on the glass cover (Fig. 3).

The aluminum plate was procured and set apart out to the fundamental size as indicated by the initial design of the authors. The aluminum plate is an exceptionally essential segment in this model because of its properties that include high thermal and electrical conductivity. A hacksaw did the cutting of the thick aluminum plate. It is a fine-toothed saw, principally produced for cutting metal and other materials such as plastic and wood. It has a C-shaped frame together with a plastic or wooden handle and a blade under tension. A hammer performed the bending process and the bench vice which is used to hold the aluminum plate in place for hammering and shaping. The marking of the aluminum plate was performed by a center punch tool which was able to mark the points for drilling and the areas on the aluminum plate for cutting. The inner view of the aluminum lining in the collector and hanger chamber is shown in Fig. 2 below. The hanger chamber is where the fruit is kept for drying. The collector chamber is where the solar heat is generated for the drying. The ventilation compartment is where fan is installed to drive the heat generated into the hanger chamber. The heat transport pipe is meant to convey the heat into the hanger chamber. The exit pipe transports moisture (from the fruit) and heat out of the system.

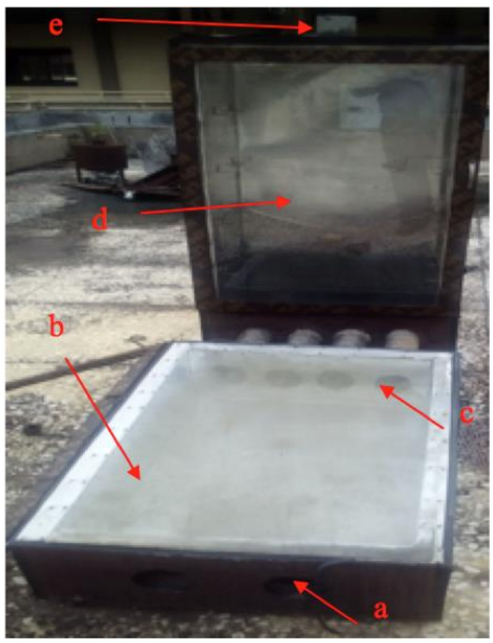

Fig. 1. Solar fruit drier.

Fig. 2. Inner view of the solar drier.

Digital thermometer placed was used to measure the temperatures in the hanger and collector chamber on a 30 minutes' interval from 12 pm to 2:30 pm daily.

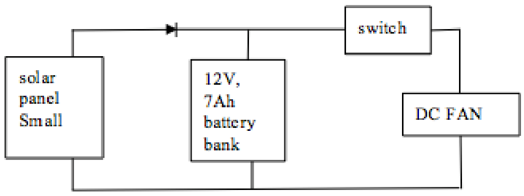

Fig. 3. Electrical circuit for the fan.

5. Results and Discussion

The temperature in the collector chamber was measured as shown in Fig. 4. Within the four days' measurement, the temperature between 12:30 pm -1:00 pm was highest in day 1. The temperature decreased due to the convective nature of the region [6]. The same pattern was seen in the hanger chamber (Fig. 5). The comparative analysis between collector and hanger chamber is shown in Figs. 6.

The temperature between 2 pm -2:30 pm was highest in day 2. The temperature between 12:30 pm -1:00 pm was highest in day 3 and the temperature between 1:30 pm -2:00 pm was highest in day 4. It is observed that the design allowed the temperature inside the hanger chamber to increase by 15.2 %, 16.04 %, 20.14 % and 13.57 % in day 1 day 2, day 3 and day 4 respectively.

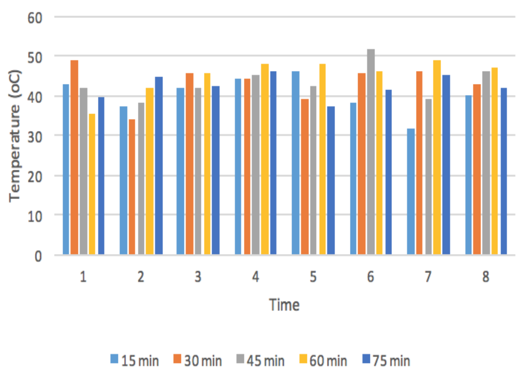

Fig. 4. Temperature progression in the collector chamber.

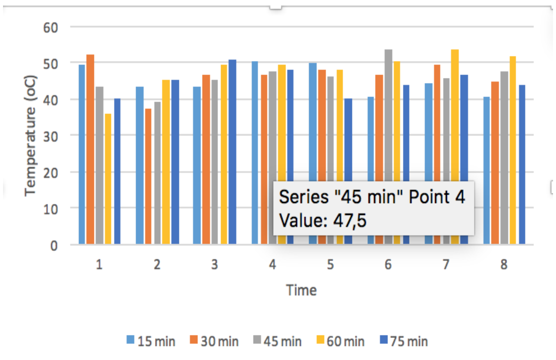

Fig. 5. Temperature progression in the collector chamber.

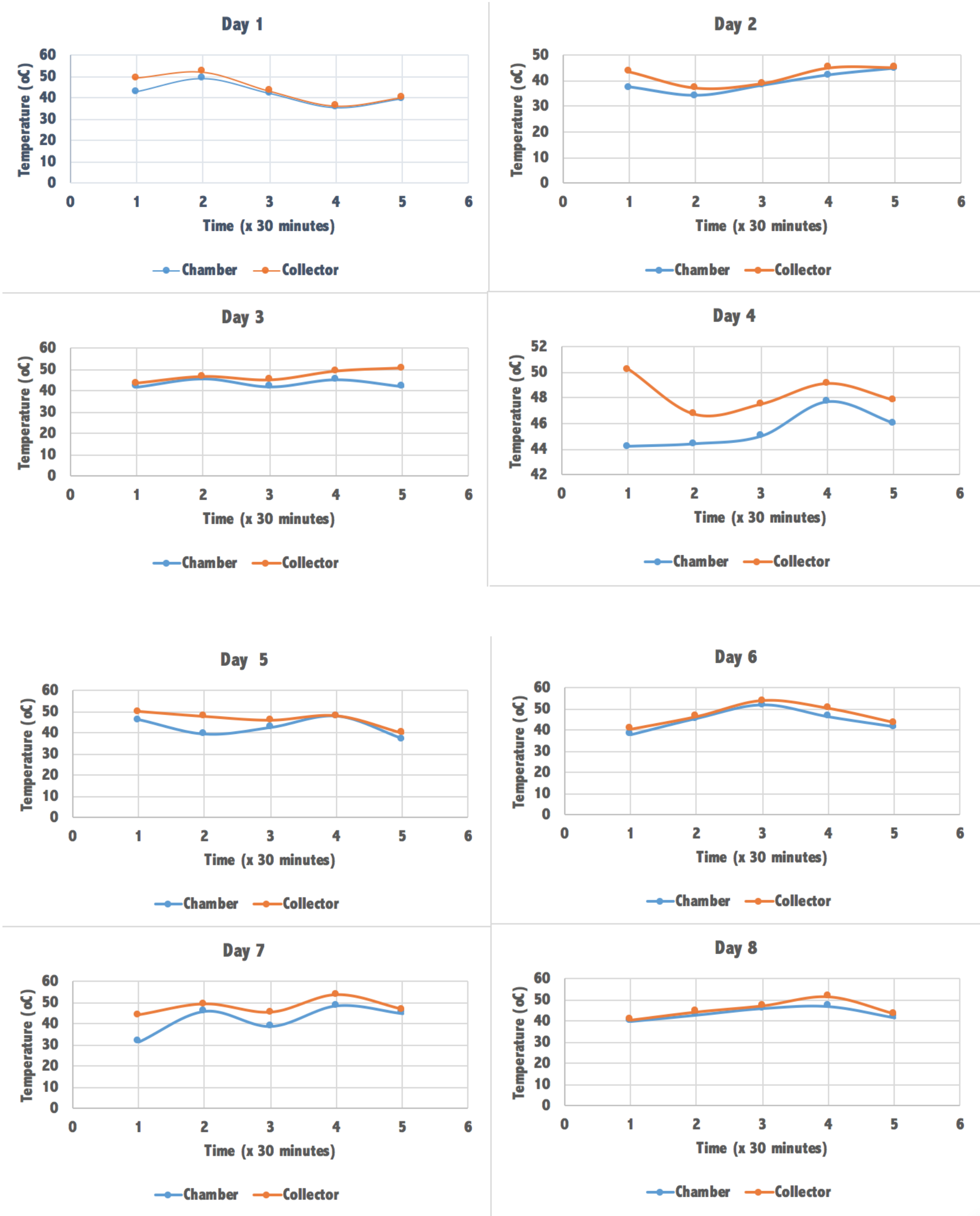

Fig. 6. Comparative analysis of collector and hanger chamber in day.

6. Conclusion

The comparative analysis of the collector and hanger chamber revealed that there was an increase in the hanger chamber by 15.2 %, 16.04 %, 20.14 % and 13.57 % in day 1 day 2, day 3 and day 4 respectively. This means that adequate heat was transferred by convection from the collector into the hanger chamber. The material can be adjudged appropriately for the pilot study. However, using curved mirrors can optimize the lining within the collector chamber. Hence, the base of the collector is not expected to be rectangular but parabolic. Above all the mentioned optimization processes, the performance of the device depends on the average solar irradiance over the geographical area.

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