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Thermal Analysis of a Solar Dryer with Parabolic Collector

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Abstract: A nation's economic development can be measured by the capacity to effectively and efficiently convert energy resources into useful energy. Solar energy is an abundant energy in our country all year long. Burkina Faso is a country which has a very significant potential for sunshine almost all year round. Therefore, it is advantageous to create devices that will work through this energy resource. These devices can be used for many applications in thermal solar field like heating, cooking and drying. The parabolic trough type dryer is a device consisting of three elements: the concentrator, the collector and the drying chamber. It produces heat through the flow of air by natural convection within it. This device has the role of drying agricultural products. In this work, our task was to carry out temperature measurements of the air inside the parabolic collector solar dryer to determine the types of agricultural products that it can dry. The thermal behavior of the air inside the parabolic solar collector dryer is analyzed. The results show that the temperature of the air at the inlet of the collector increases by 9°C after passing through it and then decreases slightly before reaching the drying chamber. The difference in air temperature between the positions of rack 1 and 2 varies between 2°C to 3°C.

Keywords: Solar, Parabolic, Collector, Thermal, Dryer

1. Introduction

Solar energy transforms solar radiation into heat energy to dry food and plants [1]. In many nations, agricultural products, particularly vegetables and fruits, are lost for over 40% of postharvest through spoilage [2]. It is therefore inevitable that solar dryers are used for dry agricultural products, as discussed in the study of Kalbande et al. [3].

Burkina Faso is a country which has a very significant potential for sunshine almost all year round. The data received from the Directorate General of Meteorology of Burkina Faso have made it possible to estimate the average relative humidity of the air at 50% during the last five years from 2015. According to the summit of ECOWAS experts, on solar equipment held in Ouagadougou in September 2016, Burkina Faso has the best sunshine in West Africa [4]. Thus several solar devices have been created for the exploitation of this free energy. Among these equipments, we can cite solar dryers, solar cookers, adsorption solar refrigerators, etc.

Several solar dryers have been designed to ensure the accelerated drying of products while maintaining their nutritional qualities [5-10]. They vary depending on the design technology, the product to be dried and how they receive solar radiation. Udomkun et al [11] carried out in 2020 a report on the various solar dryers designed in Africa and Asia to show its innovative contribution to the peasant community.

The performance of a dryer depends on its collector. Thus, to design a solar device with better efficiency it is most important to determine the amount of energy actually available at various orientations of collector [12]. The studies carried out by Germain W. P. Ouedraogo et al have shown that the solar tower drier's 4m² surface insulator only produces drying air with a maximum temperature of around 63°C. On the other hand, Ky et al obtained 71°C with three hemispherical concentrators with a total surface area of 0.32 m².

In this manuscript, the choice of a cylindrical-parabolic collector as an air collector appears to be an alternative because it occupies less surface area and has a good performance at the low energy densities of the incident solar radiation [13]. It will be attached to a drying chamber, thus forming an indirect solar dryer. This dryer is in addition to the many indirect solar dryers already produced, the thermal behavior of which we will analyze.

In this study, we analyze the thermal behavior of the air inside the parabolic concentrator solar dryer.

2. Description of the Dryer

The solar dryer is represented by figure 1.

Figure 1. *Picture of the solar dryer [13].*

This solar dryer was designed and built at the Laboratory of Renewable Thermal Energies (LETRE) of University Joseph KI-ZERBO (Burkina-Faso).

It consists of two essential parts, as shown in figure 1:

1: The cylindro-parabolic insolator;

2: The drying chamber.

2.1. Cylindro-parabolic Collector

The cylindrical-parabolic collector is represented by figure 2.

Cylindrical in shape and parabolic in section, called cylindro-parabolic, the solar concentrator has an exposure area of 1×0.5 m^2. The reflector section was made from 3 pieces of 2 mm thick sheet metal and the absorber is a black painted tube 140 cm long, 10 cm in diameter and 1mm thick.

Figure 2. *Picture of the cylindro-parabolic collector.*

2.2. Description of the Dryer Chamber

Figure 3 shows the drying chamber.

Figure 3. *Picture of the drying chamber.*

The parallelepiped shaped drying chamber is constructed from local materials with sides insulated with 3 cm thick polystyrene. The drying chamber of dimensions 80 cm x 50 cm x 47 cm, contains 5 racks spaced 10cm apart from each other. In this study two racks were considered whose location is: rack 1 is located above rack 2 in the direction of air flow inside the drying chamber.

3. Operation of the Device and Experimental Protocol

3.1. Operation of the Device

The present dryer is supplied by a concentration collector, the general principle of which is to return the parallel rays of the sun, incident on its exposure surface, to a target (focus) of smaller area, where the receiver is housed tubular blackened [14]. The black paint allows the absorber to retain a maximum amount of sunlight. It is enveloped by pieces of transparent glass, opaque to infrared. Another advantage linked to this envelope is to limit the enormous radiative and convective losses. Thus, a greenhouse effect is created in this concentric receiver, applied to a solar dryer. This greenhouse, in addition to trapping infrared rays from direct radiation, will be responsible for the increase in air temperature. This thus promotes its natural flow to the drying chamber and then emerges through a capped chimney, placed on the cabinet, allowing the charged air to be drawn in after passing through the wet product.

3.2. Experimental Protocol

The temperature and irradiation measurements were carried out on October 25 and 26, 2018 using a data logger (midi logger GL200) equipped with type J thermocouples and a pyranometer. The recorded data are:

1) Solar irradiation;
2) Ambient temperature;
3) Air temperature at the insolation inlet;
4) Air temperature at the outlet of the insulation;
5) Air temperature in the chamber at the level of the 1st hurdle;
6) Air temperature in the chamber at the level of the 2nd hurdle.

The accuracy of these devices is 1% for temperatures between 20°C and 50°C.

4. Results

The climatic conditions (solar irradiation, ambient air and drying air temperatures) for October 25 and 26, 2018 are as follows.

4.1. Solar Irradiation

Figure 4 shows the variation of solar irradiation during the days of October 25 and 26, 2018.

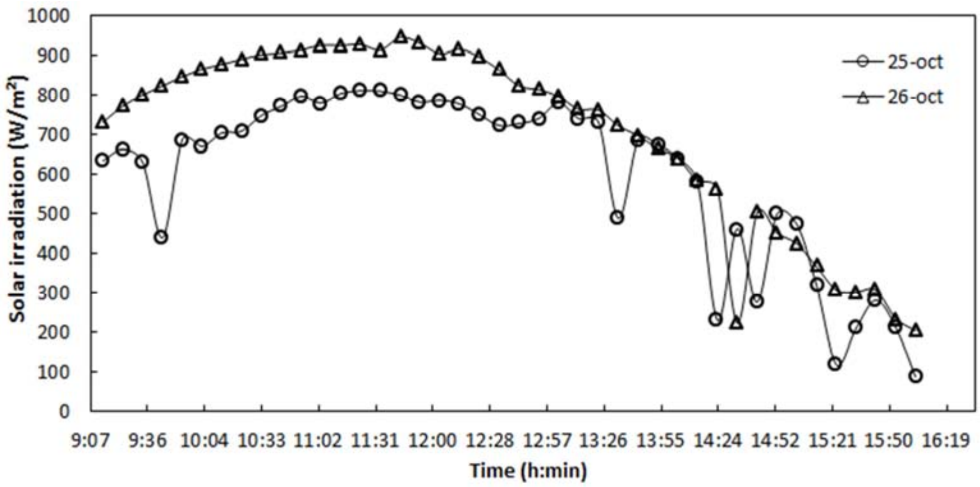


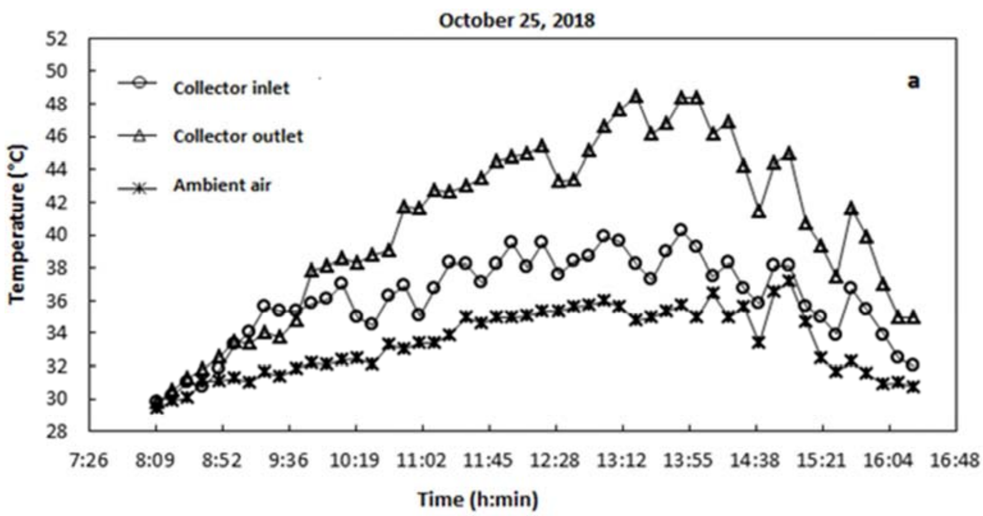
Figure 4. *Variation of solar irradiation over time.*

We observe a fluctuation of solar radiation during these two days. The sudden drops in radiation observed on the irradiation curves are caused by the passage of clouds. The average solar irradiation of these two days is approximately equal to 653 W/m².

4.2. Temperature of Air in the Collector

Figure 5 (a and b) shows the variation of the air temperature in the collector.

We observe in these curves of Figures 5 (a) and (b) that the air temperature at the outlet of the collector is higher than that at the inlet and this due to the parabolic-cylindrical concentration system. In fact, the air entering the collector at ambient temperature receives sensible heat from the concentrator and increases its temperature by up to 9°C during the day. This temperature is slightly higher than that entering the drying chamber.



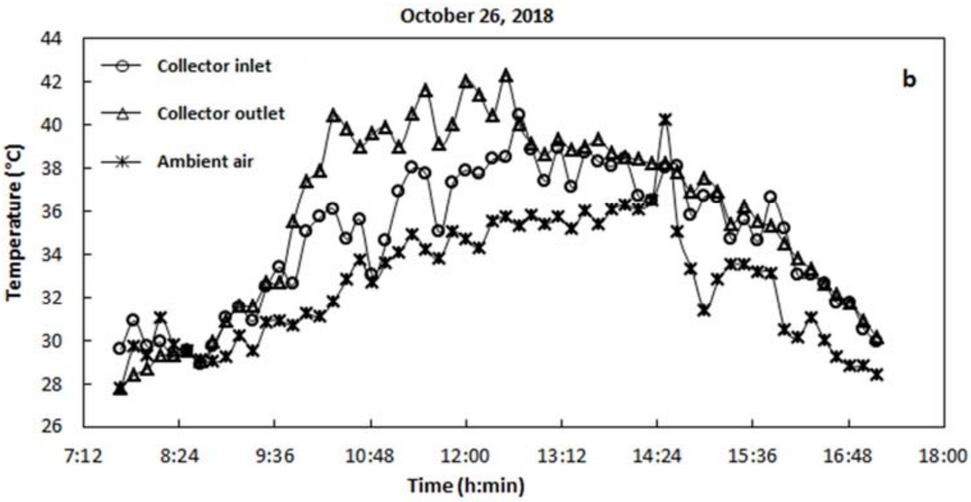


Figure 5. *Evolution of air temperature on October 25 and 26, 2018 in the collector.*

Figure 6 (a and b) shows the evolution of the temperature of the air in the dryer chamber during its passage at the level of racks 1 and 2.

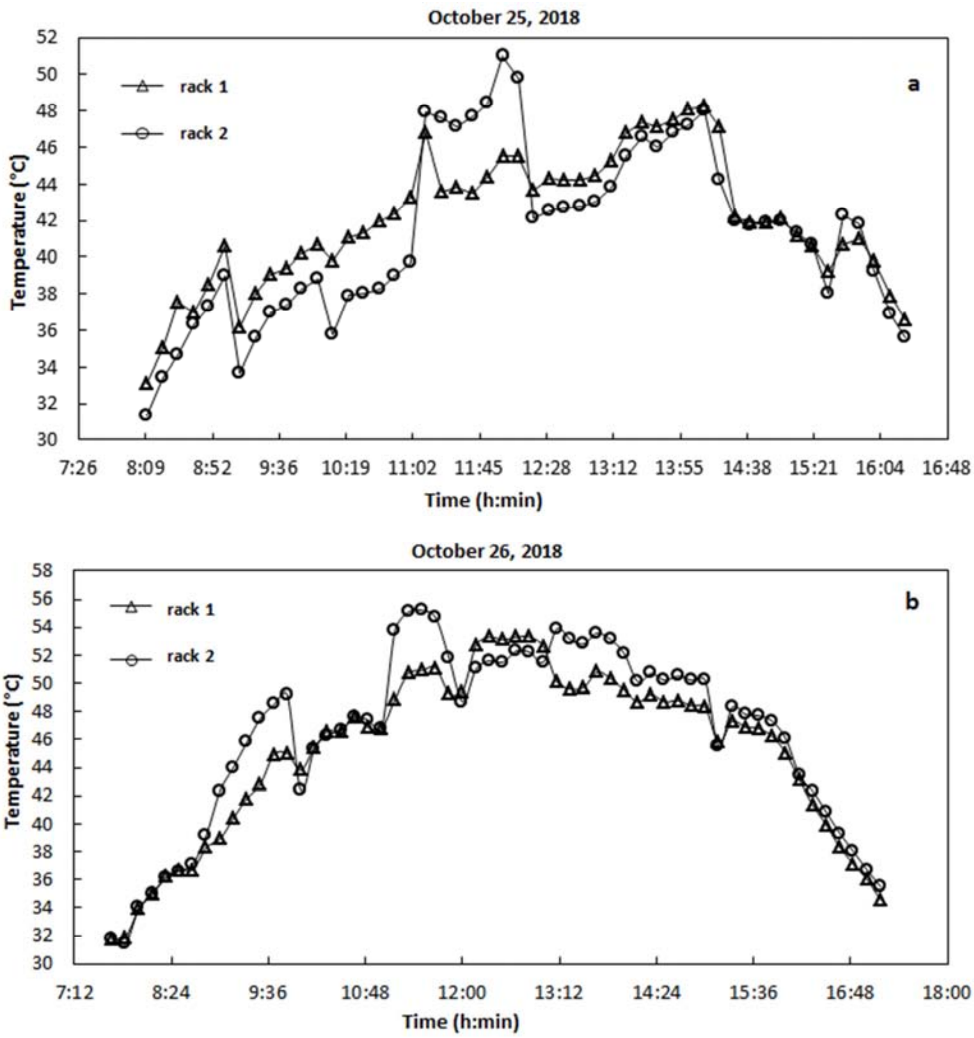


Figure 6. *Evolution of air temperatures in the dryer chamber on October 25 and 26, 2018.*

Figures 6 (a) and (b) show the evolution of the air temperature at the level of rack 1 and 2 during the two days. The average differences between the air temperatures at the level of the rack 1 and those at the level of the rack 2 are relatively small (around 2°C). The maximum temperatures at shelf 1 are 48°C and 53°C respectively for October 25 and 26, while those of the air at shelf 2 are 51°C and 55°C respectively for October 25 and 26. Rack 1 is located above rack 2 in the direction of air flow inside the drying chamber.

The temperature range being between 32°C and 55°C shows that the device can dry products with low or high water content such as okra, onion, banana, tomato, cassava, etc.… [15].

5. Conclusion

The experiments carried out show that the temperature of the air at the inlet of the collector increases by 9°C after passing through it and then decreases slightly before reaching the drying chamber. The difference in air temperature between the positions of rack 1 and 2 varies between 2°C to 3°C.

This parabolic dryer gives possibility to dry different types of foods with low or high water content.

In perspective, we will be able to:

1. dry the onion with a cutting shape (cylindrical);
2. study the influence of cutting on drying;
3. make a comparative study of the drying of yellow onion and red onion.

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