

Experimental Evaluation Of Thermal Performance A Air Flat Solar Collector

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ABSTRACT: Background: This article is part of the process of valuing solar energy for the conservation of agricultural products. Objective: The objective of this article is to experimentally evaluate the thermal performance of a flat solar air collector with single glazing operating in forced convection intended for heating local products. Methods: The methodology consists of following the evolution of solar irradiation, the temperature of the air at the entrance and exit of the collector, and the temperature of the absorber, thus leading to the determination of the thermal efficiency by equations found in the literature review. Results: Indeed, the curves resulting from this study all have the same pace, increasing between 7 a.m. and 2 p.m. and decreasing after 2 p.m., reaching their optimal values of 58°C, 51°C, 46°C, and 33°C, respectively, for the absorber, the air leaving the sensor, the window, and the air entering the sensor. The thermal efficiency of the solar collector varies between 0.25 and 0.57 for a speed of 2 m/s, from 0.19 to 0.54 for a speed of 1.5 m/s, and from 0.20 to 0.47 for a speed of 1 m/s. The air temperature at the sensor outlet varies from 26°C to 47°C for a speed of 2 m/s, from 30°C to 54°C for a speed of 1.5 m/s, and from 34°C to 58°C for a speed of 1 m/s. Ultimately, this article makes a contribution to the need for the integration of an auxiliary source of energy during the drying of local products. This additional source will make it possible to compensate for the energy deficits observed towards the beginning and end of the day for controlled and efficient drying.

Keywords: *Experimental evaluation, performances thermic, solar collector plan has air*

INTRODUCTION

The increase in the planetary population and the industrial development of the 20th century accentuated the exhaustive use of conventional energies, thus causing their shortage. Awareness of current issues (global warming with its consequences, depletion of resources, increase in health costs) is pushing researchers to move towards the use of new renewable energies on the one hand and the optimization of existing energy processes on the other.

On the other hand, in this context, several researchers have developed the integration of renewable energies in the heating of premises and the drying of agricultural products such as vegetables, fruits, cereals, spices, aromatic plants, wood, fish, fruit, and

cereals, particularly in the solar drying of products. The indirect solar dryer is a drying device comprising a solar collector and a drying unit (Janjai and Bala, 2012).

The essential part of this type of dryer is the flat solar air collector, which is a heat exchanger that transforms solar energy into thermal energy. It is a device that absorbs incoming solar radiation, converts it into heat, and then transfers heat to a fluid flowing through the collector (Khama et al., 2016). Taking into account the critical role played by the solar collector in the conversion of solar energy into thermal energy, several research works are carried out on flat solar air collectors in order to characterize the flow and the transfer of heat and to study the effect of collector geometry and internal and external parameters on the thermal efficiency of the solar collector.

For reference, the work of Baissi et al. (2014) and Ayachi et al. (2019) on the theoretical and experimental parametric study of a flat air solar collector showed that the solar irradiation parameters and the air temperatures at the inlet and outlet of the collector influence the instant thermal yield. They showed that increasing these parameters improves the thermal efficiency of the sensor. (Aissaoui et al., 2016) to experimentally and theoretically analyze the thermal performance of a flat solar collector. The results show a satisfactory qualitative and quantitative agreement between the numerical and experimental results. Pascal et al. (2017) have studied and modeled the parameters of a single-pass solar air collector for drying cocoa beans from Madagascar.

Also, Mokhtari and Semmar (2001) conducted an experimental study on the thermal performance of three types of simple solar air heaters. The geometries of these three configurations differ from each other in the position and shape of the flow channel. The results showed that for the measured outlet temperature, it was noticed that a better thermal efficiency was obtained for a collector. This study aims to evaluate the thermal performance of a flat solar air collector with a view to its optimization.

MATERIAL AND METHODS

2-1- Experimental Materiel

The experimental equipment used is a flat solar air collector coupled with a drying chamber designed in the Process Engineering laboratory. The two form a forced convection-type hybrid dryer (Figure 1a). Our study focuses on the solar air collector intended to heat the air necessary for drying okra. The components of this device are:

- A flat air solar collector with simple circulation and single glazing, dimensions (1.7x1x0.14) m³, i.e. an area of 1.70m², inclined of 19° concerning the horizontal and facing due south. The rear face and the side walls are insulated with 6 cm thick polystyrene
- The drying chamber of dimensions 0.8 m deep, 0.7 m wide and 0.9 m high. It has six aluminum trays, each with an area of 0.55 m²; the distance between the trays is 10 cm. The chamber is made of iron with polystyrene insulation 5 cm thick. A vacuum cleaner with a speed variator favors the suction air coming out of the sensor towards the room.
- A thermoregulator in the 0-400°C range with an accuracy of 0.01°C connected to a type K sensor acting on the auxiliary electric heater is used to set the temperature.
- Two electrical resistances of 1kW of power playing the role of auxiliary source of energy.



Figure 1: a) Hybrid solar dryer



b) Scale with an accuracy of 0.01g



c) digital solarimeter PL-110SM

2-2-Methods

The experimental method consists of daily carrying out during the drying of the gombo the temperature measurements and the solar radiation each 30 minutes

The experimental study on the sensor, consists of the measurement:

- Total solar radiation received in the field of the sensor using a polarimeter whose results obtained are posted numerically;
- Temperatures using the thermo hydrometers at the entry, the exit of the sensor, and ambient conditions;

2-3-Data analysis

Thermal efficiency of the solar collector

The instantaneous thermal efficiency of a collector was estimated using equation 1 (Kanouté et al.,2020):

$$\eta_{th} = \frac{\dot{m}_{air} \times C_{p_{air}} \times (T_{air_{outlet}} - T_{air_{input}})}{I_g \times S_c} \quad (.1)$$

Equation (2) was used to express the airflow through the sensor

$$\dot{m}_{air} = V \cdot S_c \cdot \rho \quad (.2)$$

\dot{m}_{air} : Mass throughput of air (kg/s);

$C_{p_{air}}$: Specific heat of air (J/kg.°C);

$T_{air_{outlet}}$: Air temperature at sensor outlet (°C);

$T_{air_{input}}$: Air temperature at sensor inlet (°C);

I_g : Global solar energy received on the inclined collector surface in (W/m²)

S_c : Surface sensor (m²);

V : Airspeed in the sensor (m/s).

ρ : density of the air circulating in the solar collector (kg/m³);

RESULTS AND DISCUSSION

3.1.Effect of air velocity and global solar energy on air temperature

Figure 3 shows the evolution of the different temperatures of the sensor elements as a function of time. These curves all have the same shape, increase between 7 a.m. and 2 p.m. and decrease after 2 p.m. and reach their optimum values of 58°C, 51°C, 46°C and 33°C respectively for the absorber, from air to the outlet of the sensor, of the window as well as that of the air at the inlet of the sensor. The high temperature of the absorber is due to the high absorption coefficient which makes it possible to absorb most of the solar radiation; that of the glass is low compared to the other components of the collector because of thermal losses to the outside and its low absorption coefficient. It is also observed that the temperature of the air at the outlet of the sensor reaches a maximum value of 56°C, this means that the sensor has allowed a rise in temperature of approximately 18°C, which constitutes an economic gain for the energy point of view for the drying of local products. These results are similar to those found by (Kanouté et al., 2020; Pascal et al.,2017). These authors evaluated the thermal performance of solar air and water collectors.

Figure 4 shows that the daily variation of the air temperature at the outlet of the solar collector is proportional to the global solar energy and the air temperature at the inlet of the collector. We observe in this figure a maximum of the climatic parameters around 1010 W/m², 38°C, and 56°C respectively for the global solar energy, the air temperature at the inlet, and the outlet of the sensor around 14 hours. These results are similar to those found by (Boughali, 2010; Fouakeu et al., 2019) and confirm that solar energy significantly influences the solar collector's thermal performance. Indeed, the rise in the temperature of the air at the outlet of the collector is due to the increase in the temperature of the absorber which is a function of solar energy.

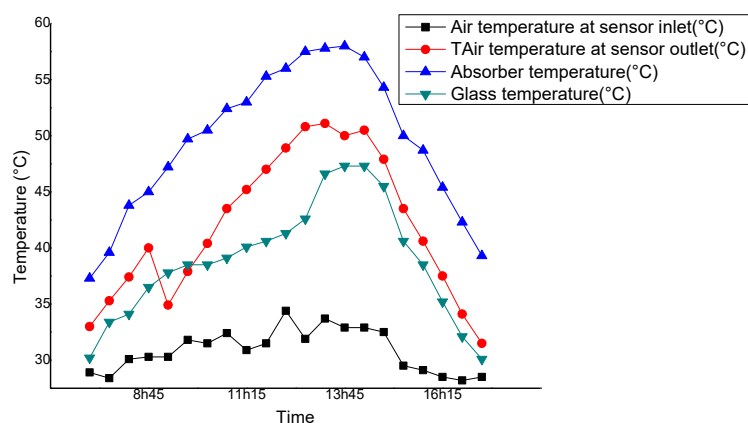


Figure 2: Evolution the Temperatures of the various elements of the collector

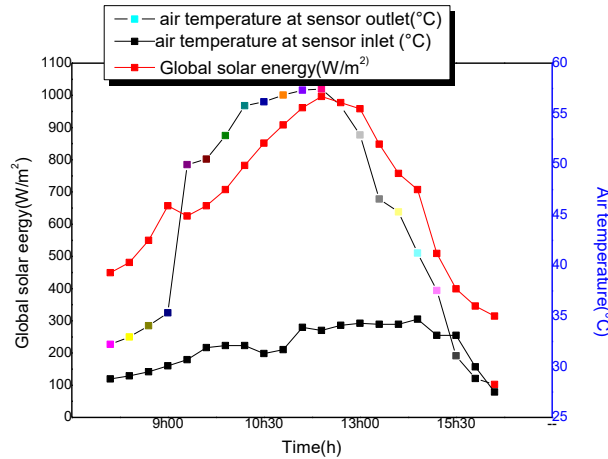


Figure 3: Evolution of air temperature and global solar energy

3.2. Effect of global solar energy on the temperature of the collector and thermal efficiency

Figure 4 illustrates the effect of air temperature on the thermal efficiency of the sensor. It is noted that the thermal efficiency is proportional to the temperature of the air at the inlet and outlet of the sensor. We also note the existence of three phases: from 7 a.m. to 8 a.m., when we record an increase in yields; from 10.30 a.m. until almost 2 p.m., high yields of up to 0.57 for an air temperature of 56 and 34 °C, respectively, at the outlet and the inlet of the sensor; and decreases after 2 p.m. until reaching low values around 5 p.m. These results align with the work of [Manaa \(2017\)](#) and [Khama et al. \(2020\)](#). Figure 5 highlights the influence of global solar energy received on the energy produced by the sensor. The energy produced by the solar collector increases with the overall solar energy received by the collector. This observation is justified by the rise in temperature of the absorber with the energy received by the sensor. This rise in the temperature of the absorber improves the transfer coefficient within the sensor with the effect of a high temperature of the air at the outlet of the sensor but also of the energy produced.

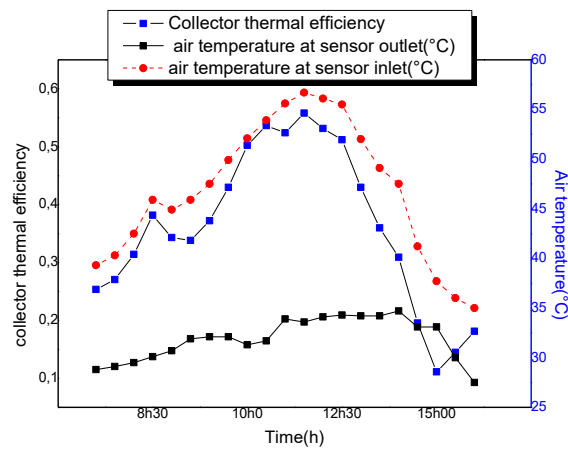


Figure 4: Evolution of the instantaneous thermal efficiency on air temperature of the air input/output of the collector

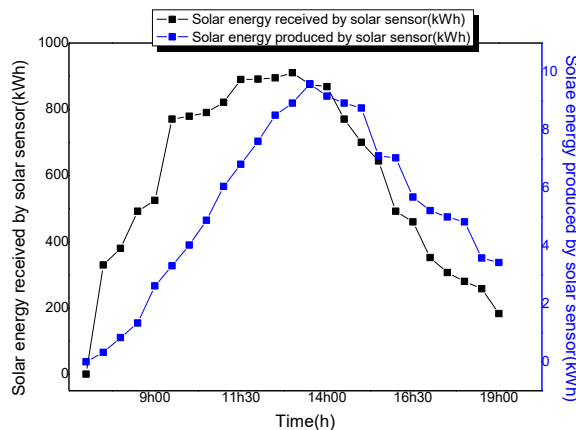


Figure 5: Evolution of solar energy received and solar energy produced by the sensor

3.3. Effect of speed air on thermal efficiency and air temperature at collector outlet

Figure 6 shows the effect of air speed on the sensor outlet's air temperature. Analysis of this figure shows that the air temperature at the sensor outlet varies from 26°C to 47°C for an air speed of 2 m/s (0.035 kg/s), from 30°C to 54°C for an air speed of 1.5 m/s (0.0275 kg/s), and from 39°C to 58°C for 1 m/s (0.020 kg/s). It is therefore clear that the evolution of the temperature of the air at the sensor outlet decreases with the velocity circulating in the sensor. Indeed, when the flow rate is low, the residence time of air within the collector increases. The heat transfer coefficient by internal convection between the absorber and the air improves by raising the outlet air temperature. These results agree with the work of [Tabet \(2016\)](#) and [Mohamed et al. \(2023\)](#).

Figure 7 shows the variation of the instantaneous thermal efficiency as a function of time for different air speed values. We note an increase in performance with air speed. This is explained by the fact that when the air speed increases, the internal convective heat exchanges are significantly improved, and the heat losses are practically constant when the airspeed increases. We note that the efficiency of the solar collector varies between 0.25 and 0.57 for an air speed of 2 m/s, from 0.19 to 0.54 for a flow rate of 1.5 m/s, and from 0.20 to 0.47 for an air speed of 1 m/s. The thermal efficiency of the sensor is not uniform and is sensitive to daily fluctuations ([Samira et al., 2015](#); [Baissi et al., 2014](#)). These results agree with those found by [Nedjemeddine \(2018\)](#) and [Mansouri \(2019\)](#).

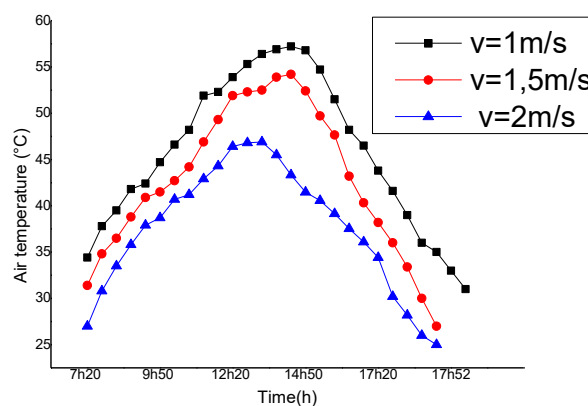


Figure 6: Effect of air speed on air temperature at sensor outlet

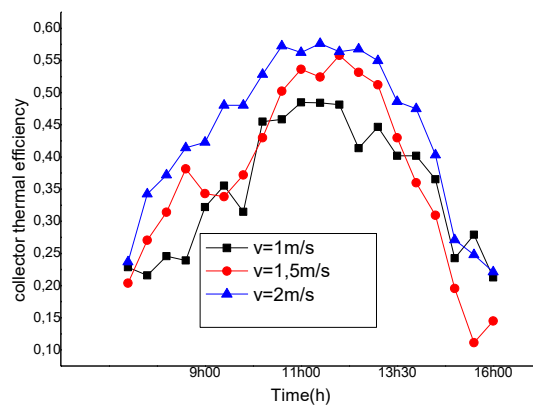


Figure 7: Effect of air speed on sensor thermal efficiency

CONCLUSION

The objective of this work is to evaluate the thermal performance of the flat air solar collector. The methodology follows the evolution over time of the parameters leading to the determination of the thermal efficiency by equations found in the literature review. The results from this study were presented as graphs. They showed that the parameters global solar energy, air speed and air temperature at the outlet of the collector influence the collector's thermal performance.

It follows that:

- ✓ The thermal efficiency increases with the global solar energy, the temperature of the fluid at the outlet of the collector and the speed of the air circulating in the collector.
- ✓ The energy produced by the solar collector increases with the solar energy received and the temperature of the air at the outlet of the collector;
- ✓ The temperatures of the air leaving the collector increase with the decrease in the speed of the air circulating in the collector and are low at the start and end of the day;

- ✓ The need to integrate an auxiliary source is obvious to compensate for the energy deficits observed at the beginning and end of the day.

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Conflict of interest

The authors declare no interest of any kind in this article.

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Contributions by each author

J.W. MAYEMBO MFOUTOU; He is the main designer of the article because this article is part of his doctoral thesis. He participated in the experimentation and data processing. **F.C.Bakeni Moukani**; She also contributed to the writing and correction of this article. **A.F.Binaki**; He contributed to the correction and acquisition of financing. **J.M NZIKOU**; He is the head of the Process Engineering Laboratory and is responsible for doctoral training, he supervises and coordinates all the research activities of the said laboratory in the search for funding, in the writing and publication of articles, doctoral theses, etc. ...

B.D.Biyendolo Loupangou; **K.E.Malela** et **S.Moussoyi Moundanga**; These authors also participated in the editing and editing of this article and the identification of this review.

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