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LOCAL RESOURCE EXPLOITATION

Analyse des performances d'un séchoir solaire indirect à biomasse (SSIB) pour le séchage de la goyave (*Psidium guajava*)

Performance analysis of a hybrid dryer: Biomass - Indirect Solar Dryer (BISD) for drying guava (Psidium guajava)

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ABSTRACT:

Drying is the most efficient way for preserving agrifood products. The randomness of the sun and the climatic conditions considerably reduce the efficiency of solar dryers despite the currently improvements made. Thus, this work is to improve an indirect solar dryer by adding a source of biomass energy. A Biomass - Indirect Solar Dryer (BISD) was designed and made from local materials. A solar energy source and an improved charcoal stove with a thermal storage system using pozzolan supply the drying chamber. The irradiance and temperature measurements for different energy combined sources (solar, biomass and solar-biomass) made it possible to characterize the (BISD). It appears that the solar collector has an area of 0.2 m² and the volume of the drying chamber is 0.402 m3. The fireplace used is a local Jambar type fireplace with volume 0.012 m^3. PCI charcoal 30 MJ/kg is used as fuel. The test with the solar collector made it possible to reach a temperature of 52 °C for an irradiation of 940 W/m² while for the different respective masses of carbon of 200, 400, 600 and 800 g in the fireplace, they obtained the respective temperatures of 40.6 °C, 55.33 °C, 63.2 °C and 62.31 °C. Storage according to a mixture proportion (coal –pozzolan) of 20 %, 30 % and 50 % of pozzolan fuel made it possible to reach the respective temperatures of 71.37 °C, 64.28 °C and 60.02 °C. The autonomy is respectively 02 hours 05 minutes, 01 hours 20 minutes and 01 hours 15 minutes for temperatures above 50 °C. The quantity of charcoal used is 1200 g compared to 2400 g used in the storage case in the hybrid dryer for almost the same duration and temperature. In hybrid mode, the drying of guava has a shorter drying time (7 h) compared with that obtained (26 h) in indirect solar mode.

Keywords: Solar dryer, Hybrid system, Biomass energy, Energy storage

RÉSUMÉ :

Le séchage est le moyen le plus efficace pour conserver les produits agroalimentaires. Le caractère aléatoire du soleil et les conditions climatiques réduisent considérablement l'efficacité des séchoirs solaires malgré les améliorations actuellement apportées. Ainsi ce travail vise à améliorer un séchoir solaire indirect en y ajoutant parallèlement une source d'énergie de la biomasse. Un séchoir solaire indirect à biomasse (SSIB) a été conçu et fabriqué à partir de matériaux locaux. Une source d'énergie solaire et un foyer à charbon amélioré avec un système de stockage thermique utilisant de la pouzzolane alimentent la chambre de séchage. Les mesures d'irradiance et de température pour différentes sources d'énergie combinées (solaire, biomasse et solaire-biomasse) ont permis de caractériser le (SSIB). Il apparaît que le capteur solaire a une superficie de 0,2 m² et le volume de la chambre de séchage est de 0,402 m^3. Le foyer à charbon utilisé est un local de type Jambar d'un volume de 0,012 m^3. Le charbon de bois de PCI 30 MJ/kg est utilisé comme combustible. Le test avec le capteur solaire a permis d'atteindre une température de 52 °C pour une irradiation de 940 W/m² tandis que pour les différentes masses respectives de charbon de 200, 400, 600 et 800 g dans le foyer, on a obtenu les températures de 40,6 °C, 55,33 °C, 63,2 °C et 62,31 °C. Le stockage selon une proportion de mélange (charbon -pouzzolane) de 20 %, 30 % et 50 % de pouzzolane a permis d'atteindre les températures respectives de 71,37 °C, 64,28 °C et 60,02 °C. L'autonomie est respectivement de 02 heures 05 minutes, 01 heures 20 minutes et 01 heures 15 minutes pour des températures supérieures à 50 °C. La quantité de charbon utilisée est de 1200 g contre 2400 g utilisé sans stockage dans le séchoir hybride pendant presque la même durée à la même température. En mode hybride, le séchage de la goyave a un temps de séchage plus court (7 h) par rapport à celui obtenu (26 h) en mode solaire indirect.

Mots clés : Séchoir solaire, Système hybride, Énergie biomasse, Stockage d'énergie

1. INTRODUCTION

In many countries around the world, the sun's rays are widely used as a direct source of energy for drying food products. Solar drying, as a means of preserving food, has been considered the most widely used system (Nasri & Belhamri, 2016). The availability of food is a real problem, as soon after the harvest season, some products are not available on the market. When these are available, their quality is poor due to deplorable conservation practice (Vengsungnle et al., 2020).

There is therefore a problem linked to food security which has negative repercussions on the local economy. Drying appears to be the best way to stabilize these products for later use, as it reduces the volume of water in the products to more than 90 % (Tchaya et al., 2017). The development of increasingly efficient drying techniques and technologies is of interest in dealing with this problem of conservation of post-harvest products (Houssou et al., 2018). Drying can be done in different ways depending on cost and energy sources. This is how we can distinguish according to cost, industrial and traditional dryers (Okoroigwe, 2015) and according to sources, solar, biomass and fossil fuel dryers.

With regard to drying with solar energy, a major limitation is the nature of the solar radiation which is dependent on time. The availability of solar energy only during sunny hours makes it difficult to use this energy source when the sun is absent without additional auxiliary heat (Amer et al., 2010). The aforementioned problems demonstrate the importance of locating the optimum drying units for achieving the best drying qualities. Some have mitigated by using storage in phase change materials (PCM) (Aumporn, 2017) and others using mixed and hybrid dryers. These hybrid dryers use biomass and conventional energy. But the use of fossil energy pollutes the environment, its cost is high and its availability in the future is compromised (Daghigh et al., 2020).

A solar-biomass hybrid dryer for drying fruits and vegetables has been designed, manufactured and evaluated by Sethi & Dhiman (2020). The dryer can be used as a solar dryer on sunny days and as a hybrid dryer powered by solar or biomass energy during nights and cloudy days. The required moisture content of banana and chilli was reached in 18 and 22 h in the biomass-fed dryer, compared to 66 and 48 h respectively in the case of natural sun drying. Kumar et al. (2012) reviewed various types of solar dryers, namely direct, indirect, hybrid solar dryers as well as their various drying applications.

The objective of this work is to improve an indirect solar dryer by adding a biomass energy source Raw material

2. MATERIAL AND METHODS

2.1. Material

Table 1. The material used for manufacturing dryer

DESIGNATION	CARACTERISTICS	ROLES
WOOD	Thermal conductivity: 0,12 - 0,15 W/m.°C Volumic mass: 375 - 525 kg/m^3	Ensuring good thermal insulation.
TRANSPARENT GLASS	Thermal conductivity: 0,78 W/m.°C Volumic mass: 2700 kg/m^3 Transmission rate: 0,83-0,91 Thickness : 4 mm	Allows solar radiation to pass through and stops infrared radiation at the solar collector.
Smooth aluminum sheet	Thermal conductivity: 204 W/m.°C Volumic mass : 896 kg/m^3 Thickness: 0,8mm Absorption coefficient: 0,65 Emission coefficient: 0,09	Absorbs solar radiation and convert it into heat.
Matte black paint	Absorption coefficient: 0,9 - 0,95 Emission coefficient: > 0.85	Coated on the absorber to obtain the best highest absorption coefficient and lowest emission
FAN	DC 12 V 0,14 A	Provides force convection of the air in the solar collector. And stirs up the coal in the combustion chamber
Improved fireplace	Type « Jambar (Peracod & giz, 2014)	Used as a back-up source for our indirect solar dryer
Charcoal	27 < PCI < 32 MJ/kg	Combustible
Black volcanic stone	Theoretical heat capacity between 1000 et 1200 J/kg/K Thickness de 10 mm.	Store heat
Guavas (PSIDIUM GUAJAVA)		picked each morning at Maroua

2.2. Operating principle of the Biomass - Indirect Solar Dryer (BISD)

The **Biomass - Indirect Solar Dryer (BISD)** is composed of a flat solar collector operating by forced convection, a drying chamber with several racks, two chimneys and two energy sources. The heat produced by the biomass fireplace was connected to this chamber, passing through the smoke chamber. This separation chamber is made of aluminum sheet and wood as thermal insulation. . A space is included between the insulating wood and the sheet in contact with the drying chamber. The sheet will transmit heat to the drying chamber by conduction. Figure 1 shows the operating principle of the system. In fact the heat is collected and transmitted in the room and the smoke is evacuated by the chimney.

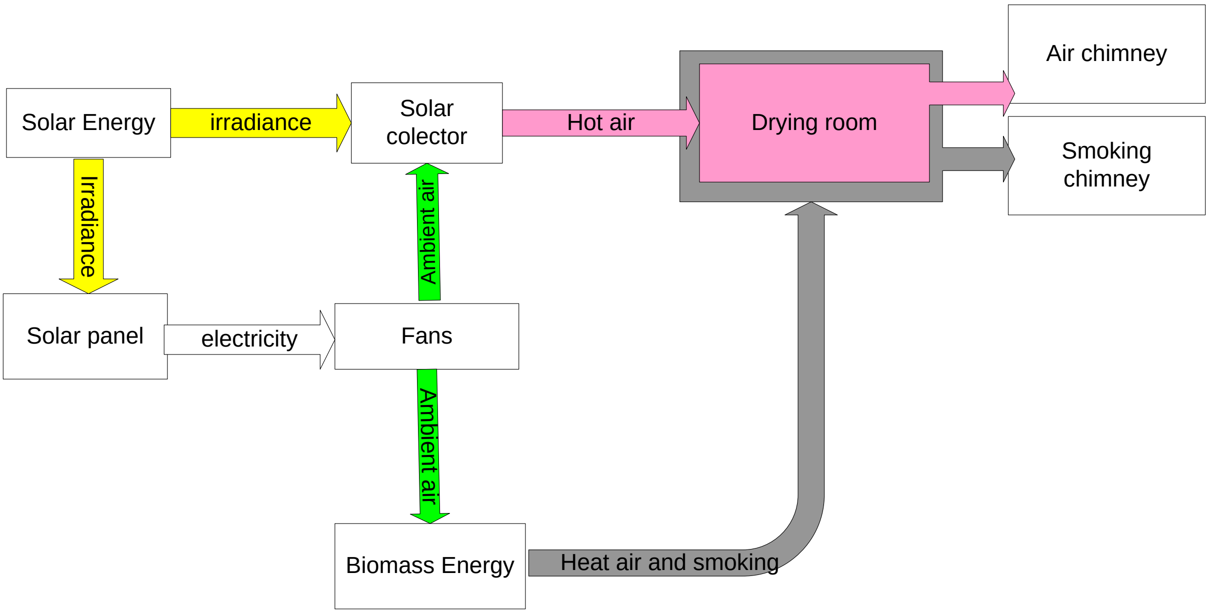

Figure 1: Functioning Principle of Biomass - Indirect Solar Dryer (BISD)

2.3. Characterization of Biomass - Indirect Solar Dryer (BISD)

To characterize the dryer, several experiments will be carried out on the device. Firstly, vacuum tests to determine the functioning of the system and secondly the drying of the guava...

2.3.1. Hybrid vacuum dryer with solar collector

The experiment involves putting the dryer in the sun, then orienting the flat collector due south for better performance. Then we place the temperature probes in the drying chamber, on the solar thermal collector and outside the dryer. The Almemo automatically records the temperature values every 5 minutes. The amount of sunlight is measured every 5 minutes using the solarimeter.

2.3.2. Hybrid vacuum dryer with biomass supply

The improved fireplace was only used in this experiment. First the coals were characterized by measuring its weight. After load the coal into the combustion chamber of the fireplace, they finally carry out the combustion.

Various tests were performed with different amounts of charcoal (200, 400, 600 and 800 g). Then the volcanic stones are used in different proportions (20, 30 and 50 %) of the amount of material to be burned. When the fire is lit the stones were added for about 10 minutes after the combustion.

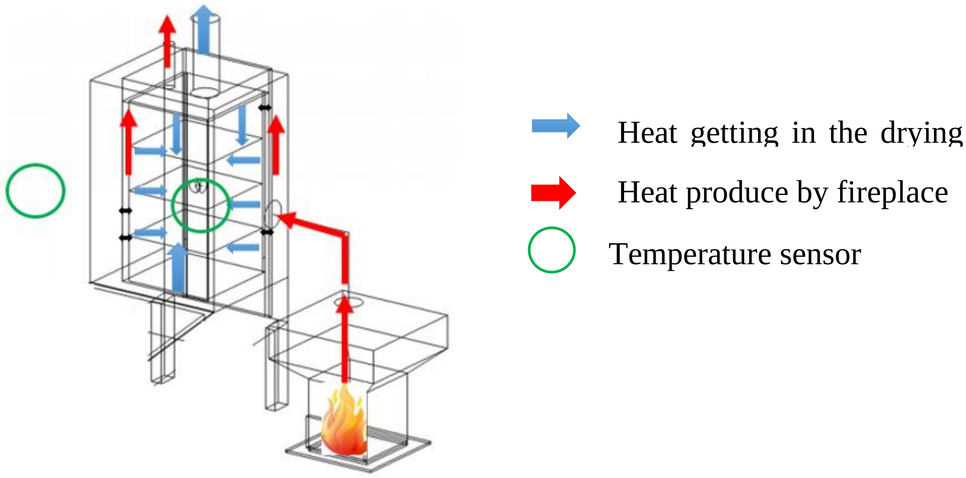

Figure 2: Functioning Principle of improved fireplace

2.3.3. Hybrid vacuum dryer combined with improved fireplace and flat solar collector

During this experiment, the solar dryer and the fireplace were used. The dryer has been exposed to the sun with the flat collector facing south for better performance. Characterized charcoal by measuring its weight is introduced into the combustion chamber of the fireplace for combustion.

After placing the temperature probes at the level of the drying chamber and outside the dryer to have the temperature at the level of the drying chamber and the ambient temperature, the Almemo automatically records every 5 minutes the values of temperature. Sunshine is measured every 5 minutes using the solarimeter.

Two experiments were carried out with 200 and 400 g of charcoal that we add every 1h30m of combustion.

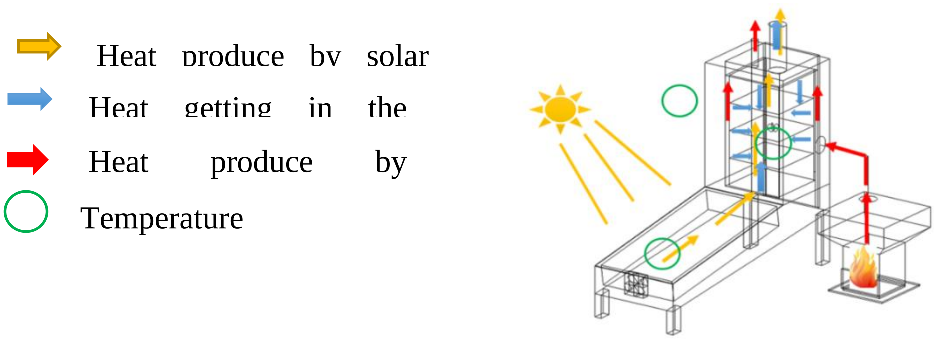

Figure 3: Experimental process scheme of hybrid dryer

2.3.4. Drying of the guava hybrid mode

The drying of the guava includes a phase of preparation, drying and conditioning. It is carried out according to the diagram below (Figure 4):

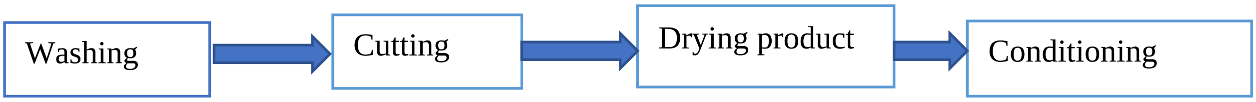

Figure 4: Principle of the preparation of drying guava

Washing guavas involves removing impurities and dirt. The guavas are then thinness cut to allow better drying. After, the product is spread in the dryer and the process is continued until free water has been removed.

A mass of 60 g of product is spread per rack. To follow the loss of mass of the product during drying, weight measurements are taken every 10 minutes then every 15, 30 and 60 minutes using a balance with digital display at 1/100. The drying kinetics of the guava are then plotted and analyzed.

3. RESULTS AND DISCUSSION

3.1. Presentation of experimental device

Figure 5 represents the hybrid solar-biomass dryer. The solar dryer is of the indirect type and the back-up source is an improved type stove whose fuel is charcoal. The solar thermal collector has an area of 0.2 m² and the drying chamber has a volume of 0.402 m3. The smoke chamber is separate from the drying chamber. This chamber is made of aluminum sheet and allows better heat exchange with the drying chamber.

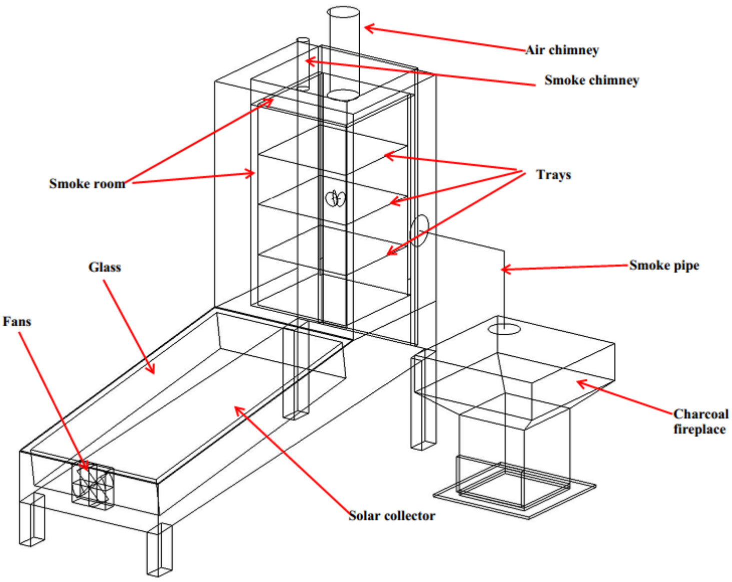

Figure 5: Descriptive diagram of Biomass - Indirect Solar Dryer (BISD)

Figure 6: Photo of Biomass - Indirect Solar Dryer (BISD)

3.2. Parameter profile with solar collector

The figure below shows the results obtained during handling with a vacuum solar collector.

During this manipulation, the chamber temperature T_{chamb} reached 52 °C. under an irradiation of 927 W/m². The ambient temperature T_{amb} reached 38.50 °C. The temperature is a function of the sunshine because the variations in the irradiance profile influence that of the temperature T_{chamb} in the same direction

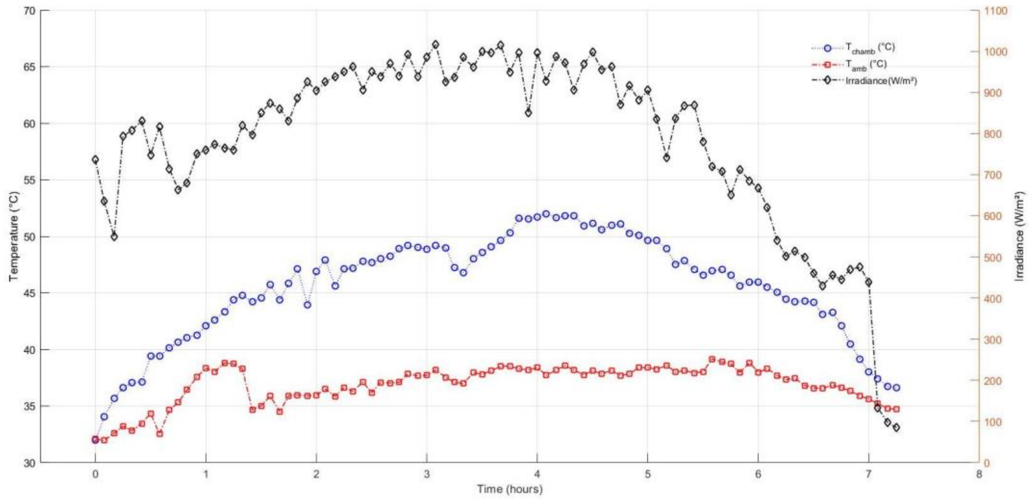

Figure 7: Temperature and irradiance profile as a function of time

3.3. Parameter profile with biomass supplying

The figure below gives the temperature profiles during the combustion of various quantities of coal.

The temperature profile shows that the heat produced is a function of the mass of coal. A temperature of 63 °C was obtained after 0.58 h for the mass of 600 g while for the mass of 800 g the temperature reached 61.71 °C after 0.92 h of operation. However

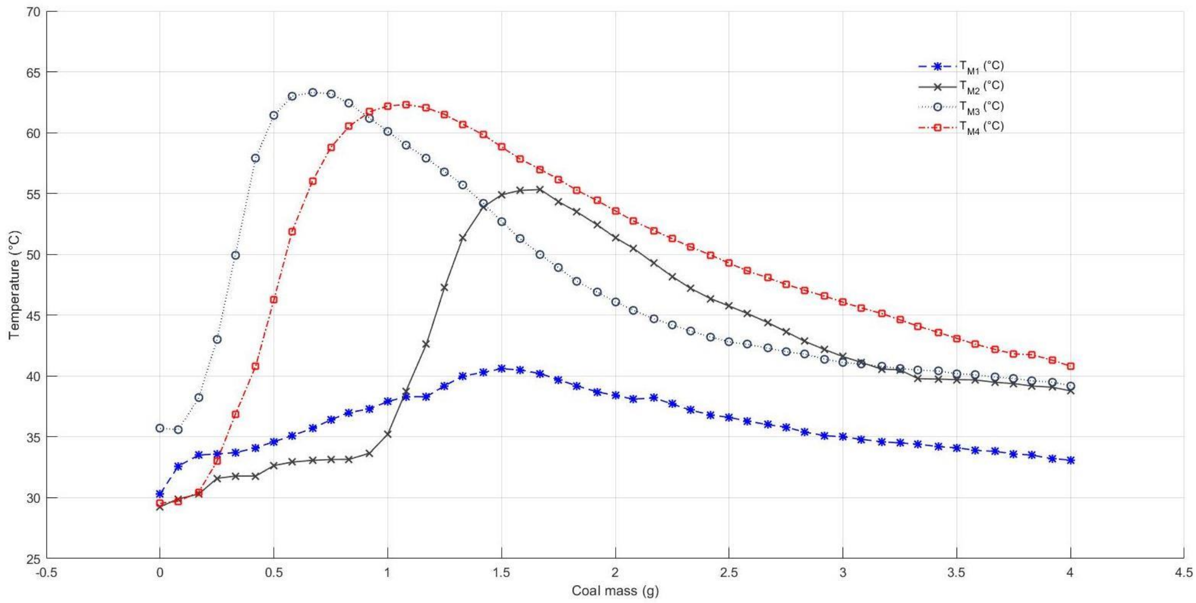

Figure 8: Temperature profile in function of time for different amount of charcoal.

For 200 g of charcoal the temperature reached 40.6 °C, and for 400 g of charcoal it is 58.33 °C and remained above 50 °C for 1 h.

For 600g of charcoal, the temperature increases rapidly and lasts 1.34h above 50 °C against 1.75h for the quantity of 800 g.

The best answers are obtained for 600 g of combustible considering the volume of the combustion chamber.

3.4. Parameter profile of the Biomass - Indirect Solar Dryer (BISD)

The figure below shows the temperature obtained during the test of the dryer supplied with solar and biomass.

The temperature of the T_{chamb} chamber has reached 67.65 °C. The temperature of the system is no longer a function of irradiation alone; it also depends on the heat produced by the fireplace. The temperature continues to rise even when the sun's radiation drops. The total amount of charcoal used up to 7.92h is 2400 g.

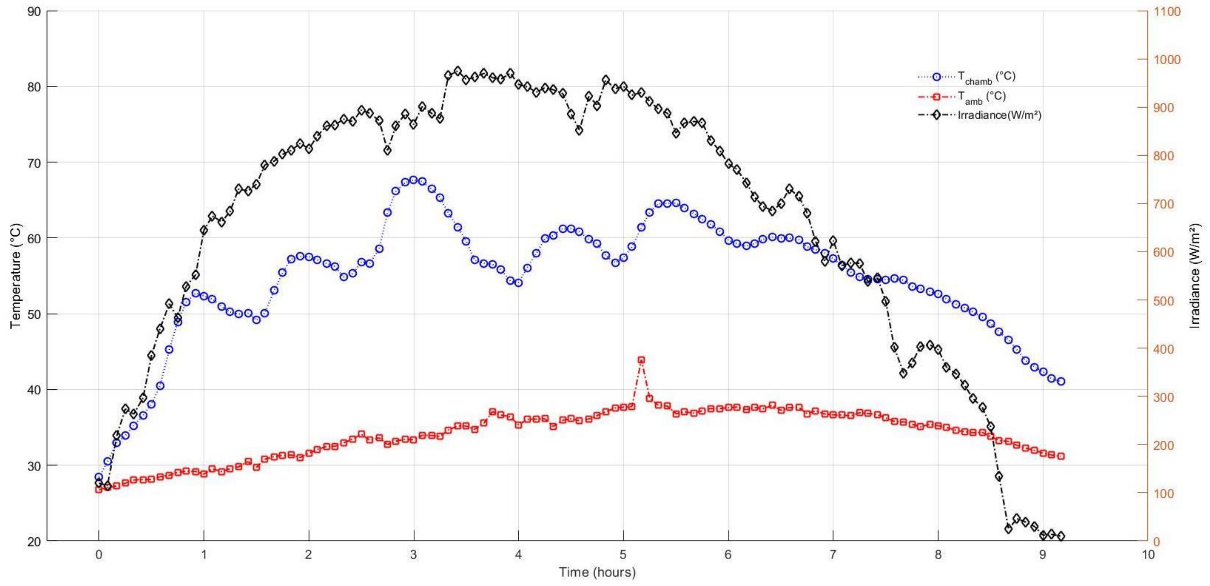

Figure 9: Temperature profile as a function of time in BISD's drying chamber

3.5. Influence of energy storage in a biomass dryer

During this experiment, various proportions of charcoal and pozzolan were used. First 80 % charcoal or 600 g and 20 % pumice or 120 g, then 70 % charcoal and 30 % pumice and finally 50 % charcoal and 50 % pumice

The figure below gives the temperatures obtained during the combustion of the various proportions of stone.

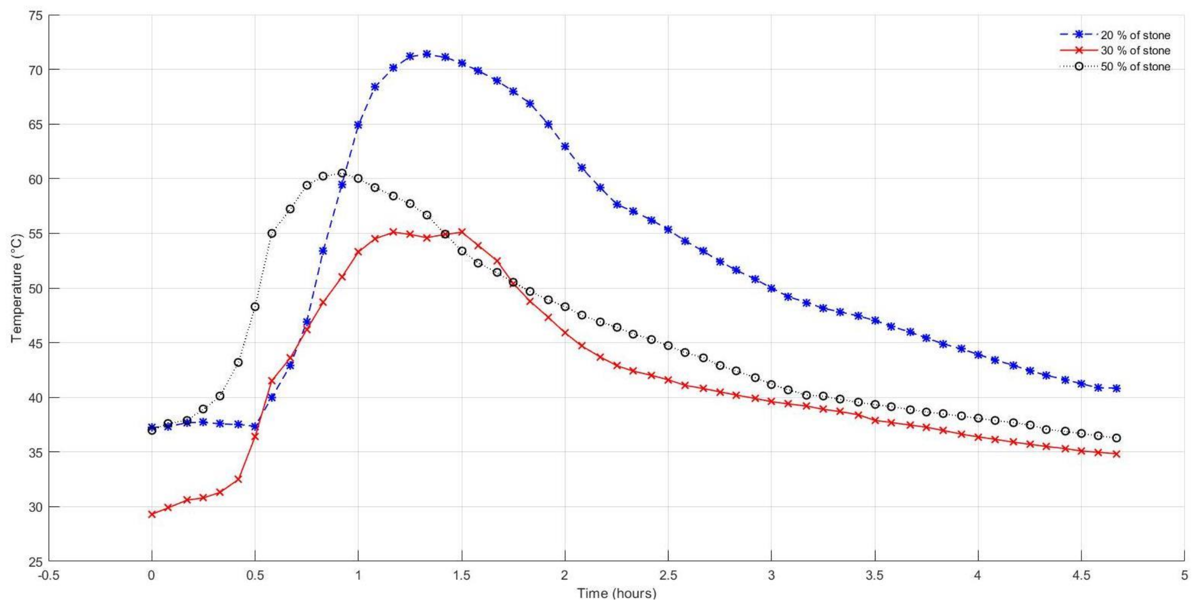

Figure 10: Temperature profile of the chamber for different proportions of stone

For 20 % stone, the maximum temperature is 71.37 °C. We were able to have temperatures above 50 °C for 2 hours 05 minutes of operation. Which shows that the stones have stored heat. The combustion lasted 4 hours 40 minutes.

While for 30 % of stone, the maximum temperature has reached is 64.28 °C. temperatures above 50 °C were obtained for 1 hour 20 minutes of operation. The combustion lasted 2 hours 40 minutes.

And for 50 % of stone, the maximum temperature reached is 60.02 °C. temperatures above 50 °C were obtained for 1 hour 15 minutes of operation. The combustion lasted 3h 10 minutes.

The best result is obtained for the proportions of 20 % stone and 80 % coal.

3.6. Influence of energy storage in the dryer

The figure below shows the temperature obtained during the test with solar biomass and storage with pozzolan. The quantity of charcoal of 600 g and the proportions of 20 % stone and 80 % charcoal were retained for the further handling.

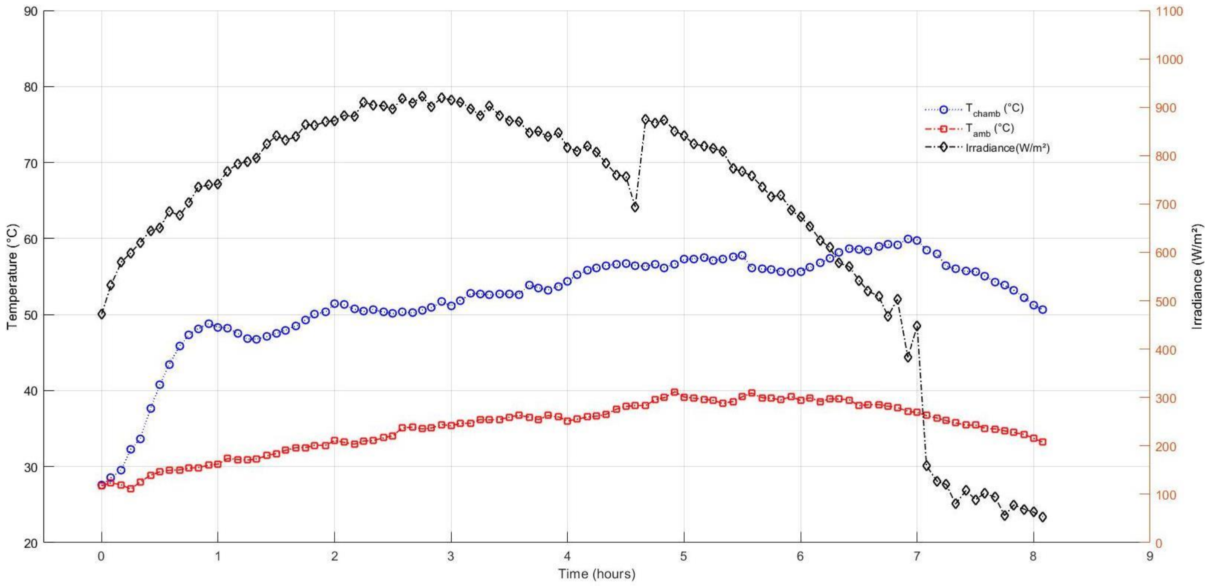

Figure 11: Temperature and irradiance profile in the hybrid dryer with storage

The temperature in the T_{chamb} chamber reached 57.78 °C and lasted more than 7 hours above 48 °C. The quantity of charcoal used is 1200 g, i.e. half the quantity used without pozzolan (2400 g). Less charcoal is used for almost the same run time and temperature.

3.7. Drying the guava

The figures below show the temperatures obtained when drying the guava with the solar collector.

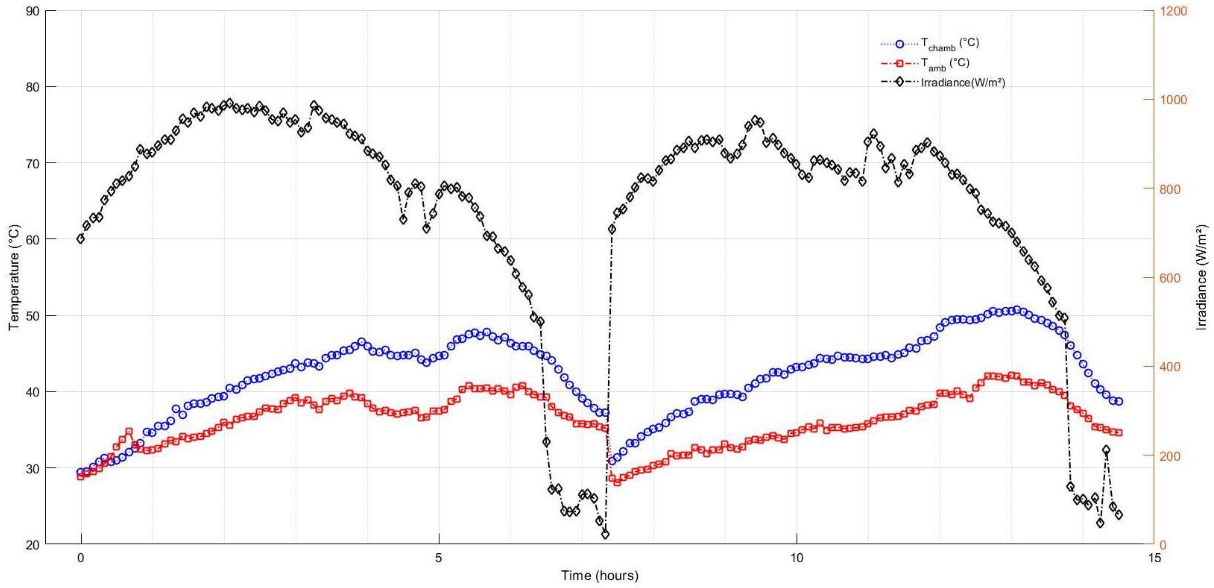

Figure 12: Profile of temperatures and irradiation as a function of time during the drying of guavas,

During the two days of drying, the temperature in the drying chamber reached 50 °C. towards the end of the handling, ie after 13 h of discontinuous drying.

3.8. Drying of the guavas in the hybrid dryer with storage

The figure below shows the temperature profile obtained when drying guava with the BISD.

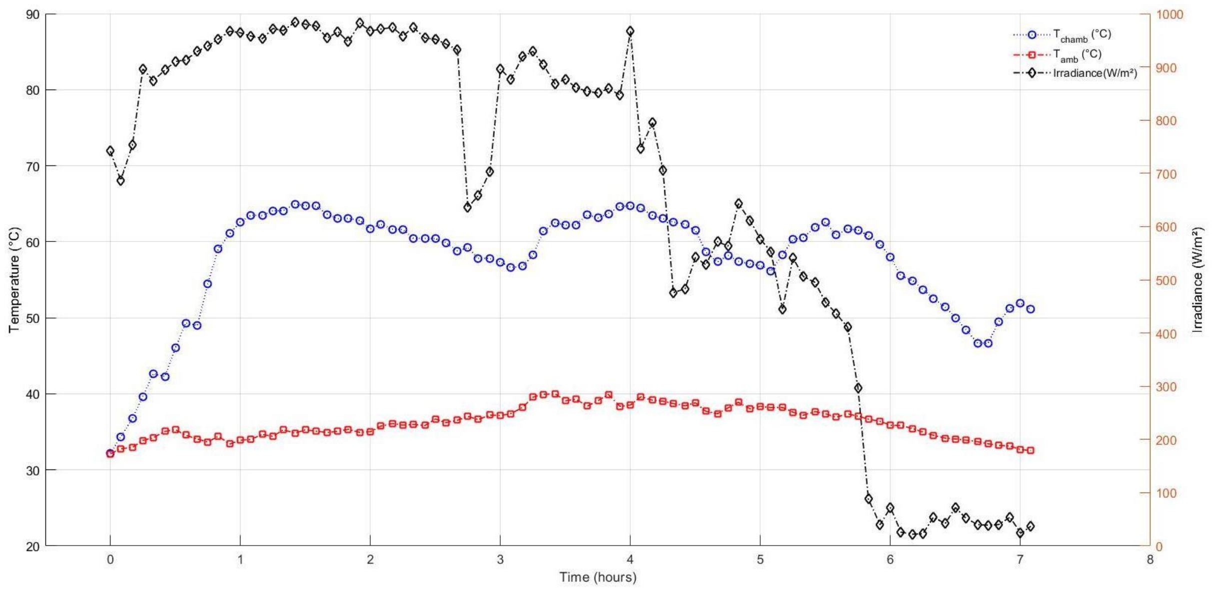

Figure 13: Temperature and irradiance profile during drying of guavas in the hybrid dryer with storage

After 45 minutes, 50 °C was reached under irradiation of 939 W/m² with T_{chamb} temperatures above 50 °C for 360 minutes or 5.8 hours despite the fluctuation of sunlight. T_{chamb} has reached 50 °C after 0.58 hours of operation.

3.9. Drying kinetics

The mass loss of the different drying modes is shown in the figure below. MH represents the mass loss of drying in hybrid mode, MS the mass loss of drying in indirect solar mode.

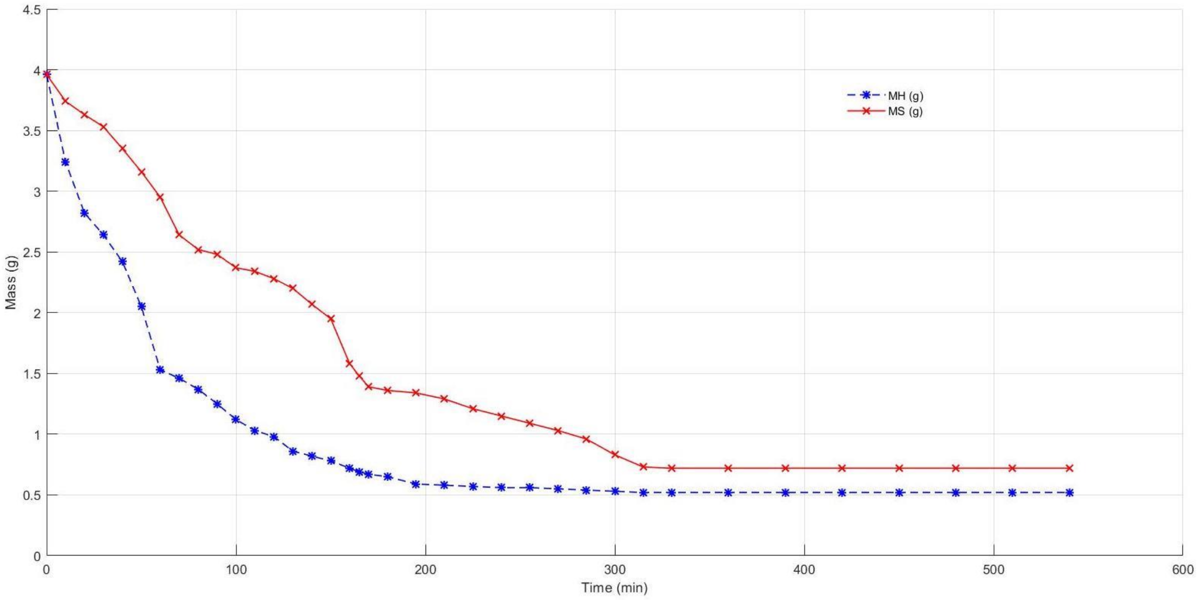

Figure 14: Guava drying kinetics

In hybrid mode, the invariant mass was obtained after 3.75 h against 7 h of time in indirect solar mode. Sekyere et al. (2016) obtained in the case of the indirect solar dryer a shortest drying time of 7 h compared to a drying time of 23 h for the drying mode under the solar.

4. CONCLUSION

The indirect biomass solar dryer (SSIB) is designed and produced in local materials with a solar thermal collector with a surface area of 0.2 m² and 0.402 m3 of volume for the drying chamber. The smoke chamber built in aluminum sheet is separated from the drying chamber and thermally insulated in wood.

Adding a biomass source improves an indirect solar dryer and saves on coal. The temperature of 50 °C, the speed to be reached there and the time to remain above this value are obtained for the quantity of carbon of 600 g per addition to the volume of the chamber considered.

By adding various proportions of pumice stone (20, 30 or 50 %) in the charcoal hearth for storage, we recorded for 20 % a high temperature above 50 °C and reaching 71.37 °C as well as the time to stay longer at 50 °C greater than the other proportions.

The quantity of charcoal used is less during storage than when using the hydride dryer without pozzolan, ie 1200 and 2400 g of charcoal. Less charcoal is used for almost the same run time and temperature. This made it possible to save on coal and improve the dryer.

5. CONFLICT OF INTERESTS

None to declare.

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