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Investigation of solar cooker applications for rural and remote areas

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Abstract

The global world requirements for solutions towards nutrition and food production problems for rural and remote areas are in constant growth. The limitation of resources remain its weakest points, water, food and energy are inextricably linked. In the present work, an experimental study conducted to deal with the problem of energy resources lack for food cooking and water boiling for drinking in remote area providing a technique that uses solar energy. A parabolic solar cooker was designed, constructed and tested under the Tunisian climatic conditions. Theoretical models were proposed to simulate the thermal performances of the solar cooker for both processes. The predictive models take into consideration the heat transfers during the process of meat grilling and water boiling and the variation of the climatic conditions. The experimentations carried out for the process of grilling meat and highlighted that the solar cooker is able to reach temperatures levels comparable to conventional cookers. The solar cooker reached temperatures above the 300°C which allows to grill the meat in an acceptable cooking time. Simulations results show that the achieved temperature by the solar cooker is suitable for different cooking processes and water disinfection by boiling. In addition, the proposed solar cooker present a solution in order to reduce the environmental impact of conventional fuels consumption. The solar cooker provides a yearly thermal energy of around 317.63 kWh. A 127.05 kg of wood could be saved which corresponds to equivalent CO_2 emissions of 123.87 kg per year.

1. Introduction

Rural and remote area communities are continuously facing the challenge of providing basic life necessities such water, food and energy. With the global warming effects, more and more areas are affected by the lack of drinking water and energy resources to prepare food or in a more correct term “Cooking”. The energy required for cooking in remote rural areas of developing countries is derived mainly from biomass fuels such as wood and charcoal. The combustion of these fuels resources leads to many environmental and health problems. Wood burning is a large source of CO_2 emissions which contributes to global warming [1]. The harvest of wood for cooking contributes to deforestation and reducing carbon uptake by forests. In addition, the pollution which occurs during wood combustion causes a variety of diseases that result from smoke inhalation [2]. On the other hand, in some remote areas like desert even the wood is not available. The basic solution for those areas is to provide a technique able to use renewable energy source to reach the boiling temperature of the water for disinfection purposes, which is sufficient to kill pathogenic bacteria, viruses and parasites [3], and the appropriate energy required for obtaining healthy consumable food “the solar cooker”.

There are several varieties of solar cookers, they have been classified into two main categories: the direct solar cookers and the indirect systems [4, 5]. For the direct systems, the cooking pot is placed directly in the solar cooker. In the case of the indirect systems, the cooking pot is separated from the collector. In this case, the solar energy is collected by an intermediate absorber and it is transported to the cooking pot using a heat transfer medium. According to Erdem and Pinar [6], the direct solar cookers are grouped in three types: panel cookers, box cookers and parabolic cookers. The parabolic solar cooker can achieve higher temperatures than the box type solar cooker and it can be used for cooking by grilling and frying process and for water boiling.

Parabolic and box solar cookers are studied by Abou-Ziyan [7] and it was found that the rate of cooking for parabolic solar cooker is higher than that for box solar cooker. According to findings by Pranab et al. [8], heating water in parabolic solar cooker is faster by comparison with box cooker type. A parabolic portable solar kitchen was studied by Arenas [9] under Spain climatic conditions. He reported that 1.5 liter of water reaches a temperature around 95°C after 90 min. Under the Indian environment the time required for heating 0.5 kg of water from 38.7°C to 95.15°C was around 40 min [10]. A parabolic dish collector cooker was tested by Aidan [11] under Nijerian climatic conditions and it was proposed as a solution for cooking to minimize the purchase of other cooking fuels. Avilés and Mauricio [12] presented a mathematical thermal model based on the energy balance equations for the different elements of parabolic solar cooker. Based on their report, a mass of water of 4.2 kg takes around 120 min to achieve a temperature of 90°C. Concerning the process of cooking meat, there is a little of investigation regarding the use of solar cooker for grilling meat [13, 14, 15].

Tunisia, as the most of the North Africa and Middle East countries, has a high level of solar potential. In Tunisia, the average daily solar radiation exceeds 7.4 kWh/m^2 in summer and still more than 2 kWh/m^2 in winter. The mean daily sunshine duration ranges from 10 to 13 h/day in summer and from 5 to 7 h/day in winter. The total insulation period is 3700 h/year and 350 sunny days per year [16]. Solar cookers can be proposed as a viable solution in many areas in Tunisia particularly in the desert regions. In fact, almost the third of the territory constituting the south regions of Tunisia is formed by desert [16]. The climate of Tunisia and most of the North Africa and Middle East region countries offers a favourable environment for the use of solar energy for cooking purposes.

In the present investigation, a parabolic solar cooker was designed, constructed and tested. The performance of the proposed prototype was studied experimentally and using simulations under the Tunisian climatic conditions. The experimental tests were carried out for the process of meat grilling. Simulations were conducted to predict the temperature achieved by the solar cooker for both processes: meat grilling and water boiling. The saved energy and the amount of CO_2 emission avoided using the proposed solar cooker was estimated for a typical year in Tunisia.

2. Material and Methods

2.1. Description of the solar cooker

The design configuration of the parabolic solar cooker is shown in Figure 1. The cooker consists of a parabolic reflector, a receiver pot and a support mechanism of the system. The proposed prototype was designed using Solidworks software. The geometrical parameters of the parabolic solar cooker are given in Table 1. The parabola geometry of the reflector is described by Equations (1)–(4).

The paraboloid shape of the reflector is defined in cartesian coordinates by:

$$X^2 + Y^2 = 4FZ \tag{1}$$

The focal distance F is defined as:

$$F = \frac{D_{ref}^2}{16H} \tag{2}$$

where D_{ref} is the aperture diameter of the parabolic reflector and H is the depth of the dish.

The rim angle ψ is the angle between the focal point and the edge of the dish and it is given by:

$$\tan\psi = \frac{F / D_{ref}}{2\left(F / D_{ref}\right)^2 - 1/8} \tag{3}$$

The aperture area is the circular surface of the dish and it is calculated using:

$$A_{ap} = \frac{\pi D_{ref}^2}{4} \tag{4}$$

The solar incident radiations hitting the interior surface of the parabolic reflector were reflected towards the focal region where the receiver pot is located. The concentrated solar radiations are absorbed by the exposed surface of the receiver and converted into thermal energy then transferred to the substance inside for cooking process. The system could be driven to continuously orient the reflector towards the sun. The tracking shall be done to keep the bright spot in the centre of the receiver surface. The design of the cooker is based on detachable parts in order to make it easy to transport, handle and mount. The assembly and disassembly of the cooker is easy and rapid so that it can be used in remote areas such as countryside, desert, camping and also for military troops in the mountains.

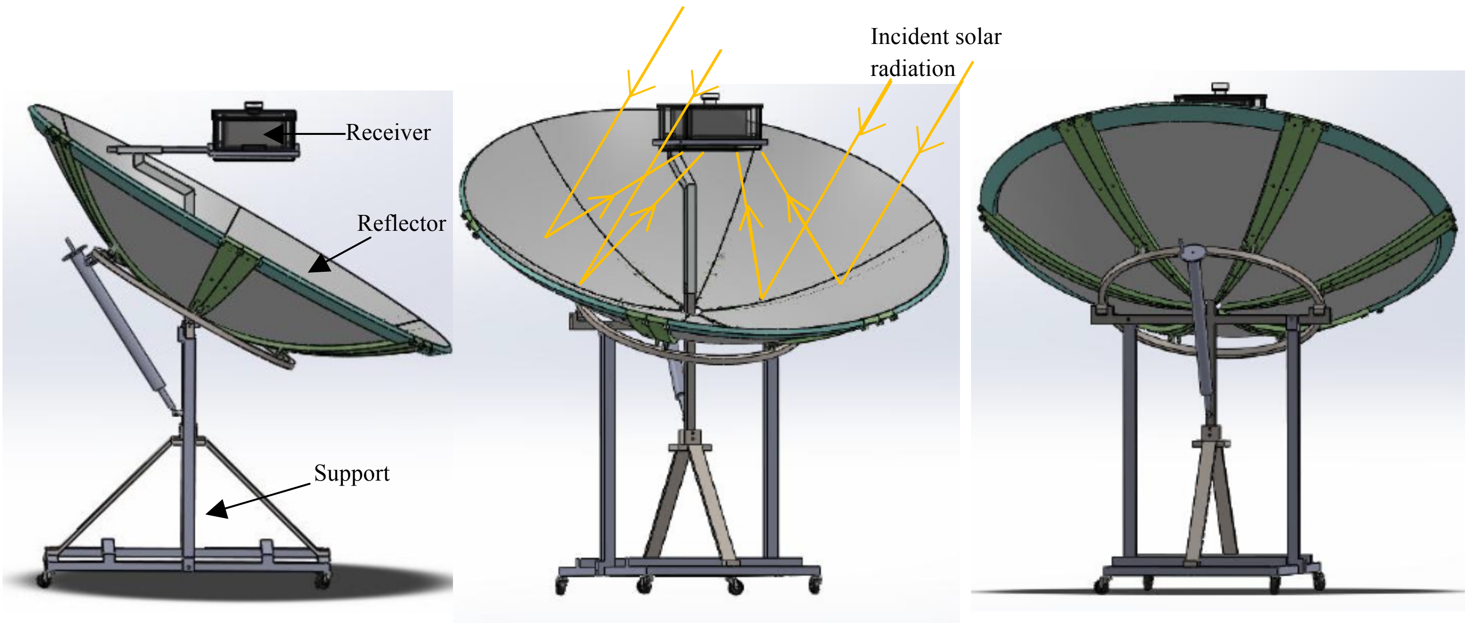

Figure 1: Design configurations of the parabolic solar cooker.

Table1: Geometrical parameters of the parabolic solar cooker.

Parabola aperture diameter	$D_{ref} = 1.2\,m$
Aperture area	$A_{ap} = 1.13\,m^2$
Focal distance	$F = 0.5\,m$
Parabola depth	$H = 0.18\,m$
Rim angle	$\psi = 47^{\circ}$

2.2. Experimental set up

The solar cooker was constructed and tested to evaluate the temperature achieved by the cooker during a cooking process. The parabolic reflector was made with fibreglass and the interior surface was covered with reflective aluminium sheets which were used to concentrate the solar energy on the receiver. The receiver used for cooking is a plate made with copper and placed in a cooking glass container. A metallic arm was used as a supports structure for the reflector and the receiver (Figure 2).

The experiments were carried out in the Research and Technologies Centre of Energy in Tunisia (CRTEn) during the month of September 2015. The solar cooker was tested for the process of meat grilling. The test starts when the receiver is placed at the focal region of the parabolic reflector which already has been oriented towards the sun. When the plate is well heated by the concentrated solar radiations we added the piece of meat. During the experiments, the temperature of the plate was measured with a Platinum resistance thermometer Pt100, the ambient temperature was determined by a K-type thermometer and the solar irradiance was measured by a Pyranometer CM 21. The measurements results were acquired by an Agilent HP 34901A 20-Channel Multiplexer.

3. Theoretical modelling and simulations

Theoretical models were proposed to simulate the performance of the solar cooker and based on the energy balance equations for the components of the solar cooker. Two receivers were used, the first was a copper plate suitable for grilling meat, whereas the second receiver was a copper cylindrical container which can be used for boiling water.

3.1. Meat grilling

The piece of meat is considered as a solid matrix composed principally by a solid mass and a mass of water. The lower surface of the plate was covered with a transparent glass. The heat transfers which occur during the grilling of meat on the plate are shown in Figure 3. The plate absorbs the concentrated solar energy and releases heat to the meat, the glass cover and the ambient air.

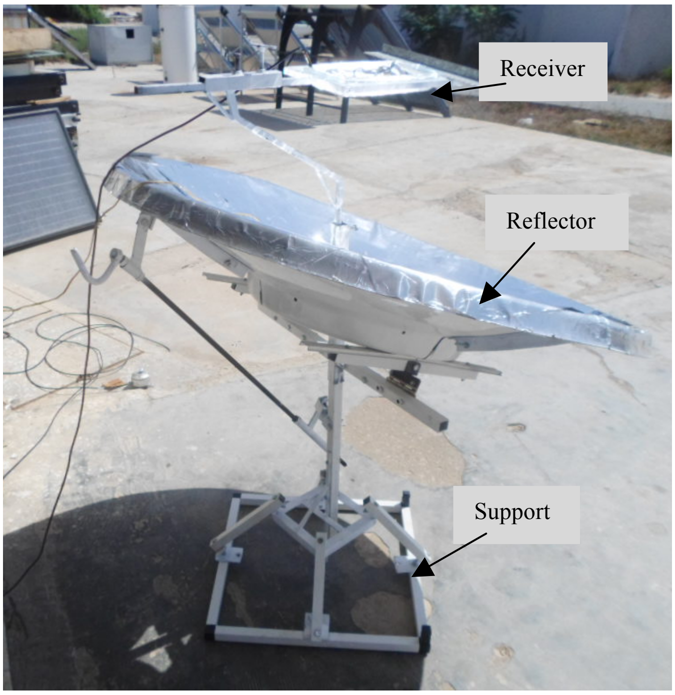

Figure 2: Parabolic solar cooker.

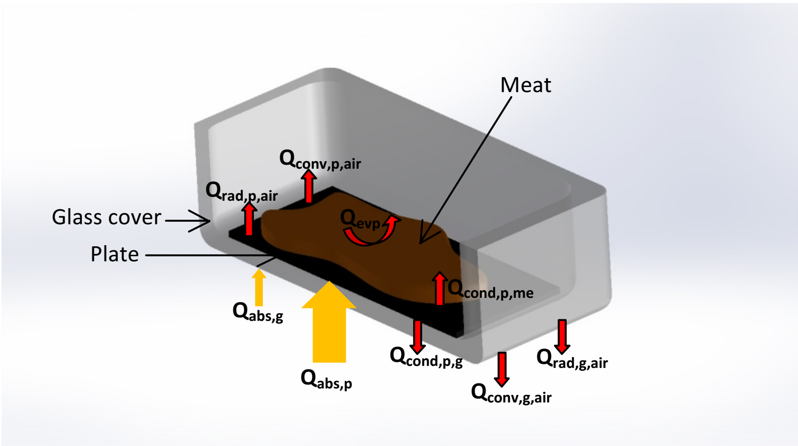

Figure 3: Schematic representation of the heat transfers during meat grilling.

- The energy balance equation for the glass cover is defined as:

$$Q_{abs,g} + Q_{cond,p,g} = m_g C_g \frac{dT_g}{dt} + Q_{rad,g,air} + Q_{conv,g,air} \tag{5}$$

The solar energy absorbed by the glass cover $Q_{abs,g}$ is given by:

$$Q_{abs,g} = \alpha_g \rho_{ref} \gamma I A_{ap} \tag{6}$$

where α_g is the glass absorption coefficient, ρ_{ref} the reflection coefficient of the reflector, γ the intercept factor, I the direct solar irradiance and A_{ap} the aperture area of the reflector.
The conduction heat transfer $Q_{cond,p,g}$ from the plate to the glass cover is estimated as:

$$Q_{cond,p,g} = \frac{A_g}{\delta_g} K_g \left(T_p - T_g\right) \tag{7}$$

where T_p is the temperature of the plate and T_g, K_g and δ_g are the temperature, the thermal conductivity and the thickness of the glass respectively.
The radiation heat transfer $Q_{rad,g,air}$ from the glass to the ambient air is estimated as:

$$Q_{rad,c,air} = \sigma \varepsilon_g A_g \left(T_g^4 - T_{sky}^4\right) \tag{8}$$

where ε_g is the emissivity of the glass, σ the Stephan Boltzman coefficient, T_{sky} is the equivalent temperature of the sky [17], and given by :

$$T_{sky} = 0.0552 T_{amb}^{1.5} \tag{9}$$

where T_{amb} is the ambient temperature.
The heat transfer from the external walls of glass to the ambient air $Q_{conv,g,air}$ occurs by forced convection and it is given by:

$$Q_{conv,g,air} = h_{g,air} A_g \left(T_g - T_{amb} \right) \tag{10}$$

The convective heat transfer coefficient $h_{g,air}$ at the outer surface of the glass is defined as:

$$h_{g,air} = \frac{k_{air}}{L_p} Nu_{L_p} \tag{11}$$

The average Nusselt number Nu_{Lp} based on the length of the plate L_p is estimated by [18]:

$$Nu_{Lp} = 0.66 \left(\mathrm{Re}_{Lp} \right)^{1/2} \left(\mathrm{Pr}_{air} \right)^{1/3} \tag{12}$$

where Re_{Lp} is the Reynolds number and Pr_{air} is the Prandtl number of air.

- The energy balance equation for the plate is defined as:

$$Q_{abs,p} = m_p C_p \frac{dT_p}{dt} + Q_{rad,p,air} + Q_{conv,p,air} + Q_{cond,p,g} + Q_{cond,p,me} \tag{13}$$

The solar energy absorbed by the plate $Q_{abs,p}$ is given by:

$$Q_{abs,p} = \alpha_p \rho_{ref} \gamma \tau_g I A_{ap} \tag{14}$$

where α_p is the plate absorption coefficient and τ_g is the glass cover transmittance.
The conduction heat transfer from the plate to the meat $Q_{cond,p,me}$ is estimated as:

$$Q_{cond,p,me} = \frac{A_{me}}{\delta_{me}} K_{me} \left(T_p - T_{me} \right) \tag{15}$$

where K_{me}, A_{me} and δ_{me} are the thermal conductivity , the surface and the thickness of the meat respectively.

- The energy balance equation for the meat is defined as:

$$Q_{cond,p,me} = (m_{me} C_{me} + m_{w,me} C_w) \frac{dT_{me}}{dt} + Q_{evp} \tag{16}$$

where m_{me} is the mass of the meat and $m_{w,me}$ is the mass of water containing in the meat.

The energy consumed by water evaporation Q_{evp} is calculated as:

$$Q_{evp} = m_w L_{evp} \tag{17}$$

where m_{evp} is the water evaporation rate and L_{evp} is the latent heat of evaporation.

3.2. Water boiling

The heat transfers during the boiling of water in the container are shown in Figure 4. The concentrated energy absorbed by the container $Q_{abs,c}$ will be divided into three parts. The first part of energy is used to raise the internal energy of the material of container and hence its temperature. The second part is transferred to the water as useful energy $Q_{conv,c,w}$. The third part is transferred from the external surfaces of container to the ambient air by radiation $Q_{rad,c,air}$ and convection $Q_{conv,c,air}$.

- The energy balance equation for the container is defined as:

$$Q_{abs,c} = m_c C_c \frac{dT_c}{dt} + Q_{rad,c,air} + Q_{conv,c,air} + Q_{conv,c,w} \tag{18}$$

The solar energy $Q_{abs,c}$ absorbed by the container is:

$$Q_{abs,c} = \alpha_c \rho_{ref} \gamma I A_{ap} \tag{19}$$

where α_c is the absorption coefficient of the container.

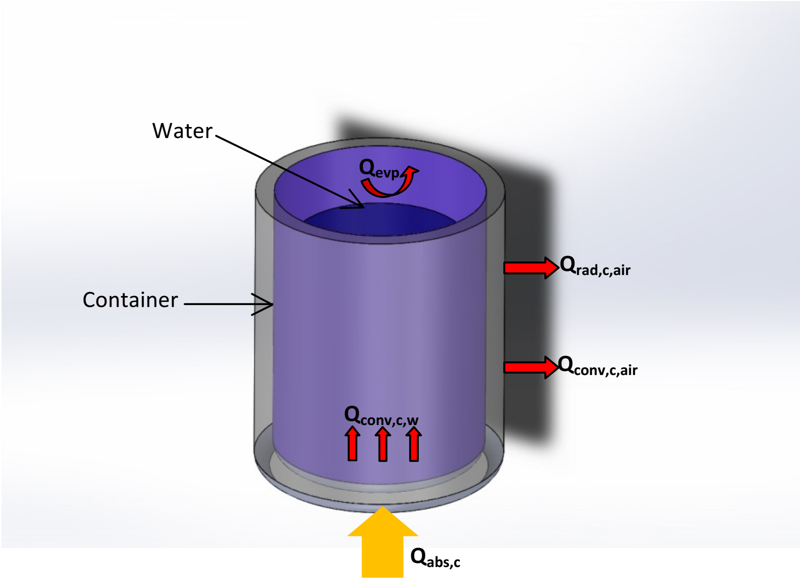

Figure 4: Schematic representation of the heat transfers during water boiling.

The radiation heat transfer $Q_{rad,c,air}$ from the external walls of the container to the ambient air is estimated as:

$$Q_{rad,c,air} = \sigma \varepsilon_c \left(A_{sid} + A_{bot} \right)\left(T_c^4 - T_{amb}^4 \right) \tag{20}$$

where ε_c , T_c , A_{bot} and A_{sid} are the emissivity, the temperature, the bottom and the side surfaces of the container respectively.

The heat transfer from the external walls of container to the ambient air $Q_{conv,c,air}$ occurs by forced convection:

$$Q_{conv,c,air} = h_{air,sid} A_{sid} \left(T_c - T_{amb} \right) + h_{air,bot} A_{bot} \left(T_c - T_{amb} \right) \tag{21}$$

The convection heat transfer coefficient $h_{air,sid}$ of the outer side surface of the container is determined from the average Nusselt number Nu_{Hc} based on the container height H_C and estimated as [18]:

$$Nu_{Hc} = 0.228\left(\mathrm{Re}_{H_c} \right)^{0.731} \left(\mathrm{Pr}_{air} \right)^{1/3} \tag{22}$$

where Re_{H_c} is the Reynolds number based on the container height.

The convection heat transfer coefficient $h_{air,bot}$ for the bottom surface of container is determined from the average Nusselt number Nu_{Dc} based on the container diameter and given by [18]:

$$Nu_{D_c} = 0.66\left(\mathrm{Re}_{D_c} \right)^{1/2} \left(\mathrm{Pr}_{air} \right)^{1/3} \tag{23}$$

where Re_{D_c} is the Reynolds number based on the container diameter.

The heat transfer inside the container $Q_{conv,c,w}$ occurs by natural convection:

$$Q_{conv,c,w} = h_w A_{bot} (T_c - T_w) \tag{24}$$

The coefficient of natural convection h_w inside the container is evaluated from the Nusselt number Nu_w suggested by the correlation of Evans and Stefany [19]:

$$Nu_w = 0.55 Ra^{1/4} \tag{25}$$

$$Ra = \frac{g \beta_w (T_c - T_w) H_c^3}{\nu_w \alpha_w}, \quad \beta = 1/T_w, \quad \alpha_w = \frac{k_w}{\rho_w C_w} \tag{26}$$

where Ra is the Rayleigh number based on the height of the container, g the gravitational constant, β the volumetric thermal expansion and α_w the thermal diffusivity of water.

- The energy balance equation for the water is defined as:

$$Q_{conv,c,w} = m_w C_w \frac{dT_w}{dt} + Q_{evp} \tag{27}$$

3.3. Simulations

The resulting model equations for the processes of meat grilling and water boiling were solved using the Engineering Equation Solver (EES) program [20]. The models were used to predict the temperature achieved by the solar cooker under variable climatic conditions. The input data of the simulations are: the geometrical, optical and thermophysical properties of the solar cooker, the solar radiation, the wind speed and the ambient temperature. The optical and thermophysical properties of the components of the solar cooker used in the simulations are given in Table 2.

Table 2: Optical and thermophysical properties of the components of the solar cooker.

Reflectivity coefficient	ρ_{ref}=0.8
Container and plate absorptance	$\alpha_c = \alpha_p = 0.8$
Glass cover absorptance	α_g=0.02
Intercept factor	γ =0.8
Container and plate emittance	$\varepsilon_c = \varepsilon_p = 0.19$
Glass cover emittance	ε_g=0.8
Glass cover transmittance	τ_g=0.95
Container and plate specific heat	C_p=380 J/kgK
Glass cover specific heat	C_g=1090 J/kgK
Container and plate density	$\rho_c = \rho_p = 8020$ kg/m^3
Glass cover thermal conductivity	k_g=1 w/mK
Glass cover density	ρ_c=2230 kg/m^3

4. Results and discussion

4.1. Meat grilling

Experimental tests and simulations were conducted to evaluate the achieved temperature by the solar cooker during the grilling of meat. The solar radiation and the ambient temperature plotted in Figure 5 were measured during the test and they were used as inlet parameters for the simulations. The results obtained from the developed model were compared to the experimental data in Figure 5. The simulated values of the plate temperatures used for the grilling of the meat were in agreement with the measured values.

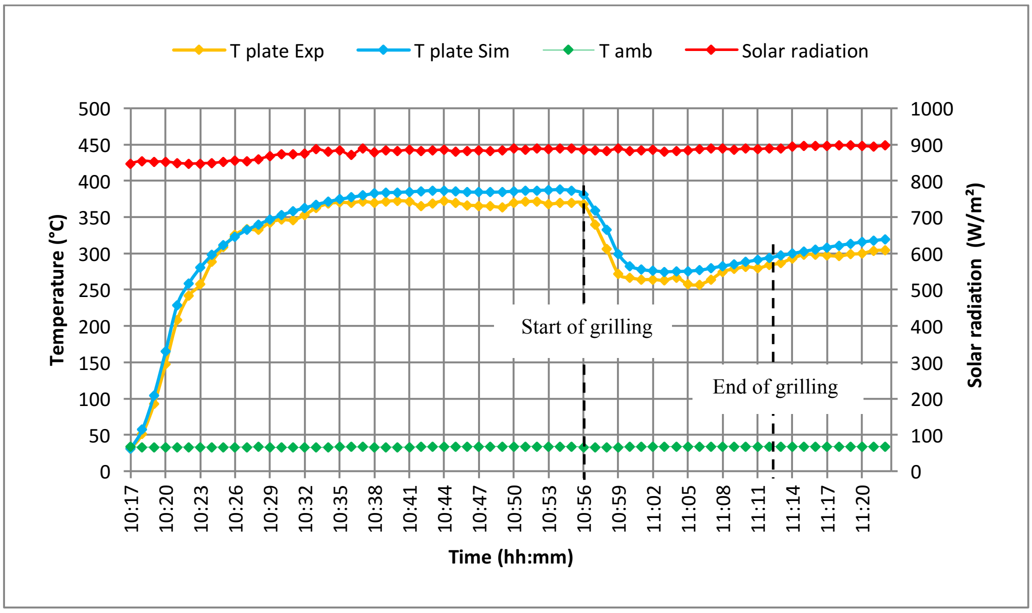

Figure 5: Experimental (T plate Exp) and simulation (T plate Sim) results of the temperature profiles of the plate, ambient temperature and solar radiation.

As shown in Figure 5, there were three distinct phases in the temperature profile of the plate: the heating period (from 10:17h to 10:56h), the grilling period (from 10:56h to 11:12h) and the period after the grilling process (from 11:12 to 11:22). The first phase is the plate heating where the receiver is placed at the focal region of the solar concentrator starting from 10:17h, the plate is heated by solar radiations which pass through the glass

cover after concentration by the parabolic reflector. The plate took around 9 minutes to reach a temperature above 300°C. The achieved temperature is suitable and equivalent to cooking process such as grilling meat, cooking pancake, chapatti or crepes in the range of acceptable times for food preparation [21, 22].
The second phase start when the piece of meat is placed on the heated plate at 10:56h (start of grilling), the temperature of the plate decreases. During the grilling process, the heat is transferred from the metallic plate to the meat's volume. The heat transmitted to the product contributed to the next thermo-physical changes state which include the temperature rising and the water content evaporation. After around 16 min the piece of meat was grilled as shown in Figure 6. Towards the end of the grilling process the third phase begin, there is a rise in the temperature of the plate again. The experimental results showed that the solar cooker allowed grilling the meat in an acceptable cooking time. Also the results proved the capabilities of such application using solar energy which is particularly important in remote areas such as desert where the solar resources are available and divers activities like civil or military are practiced.

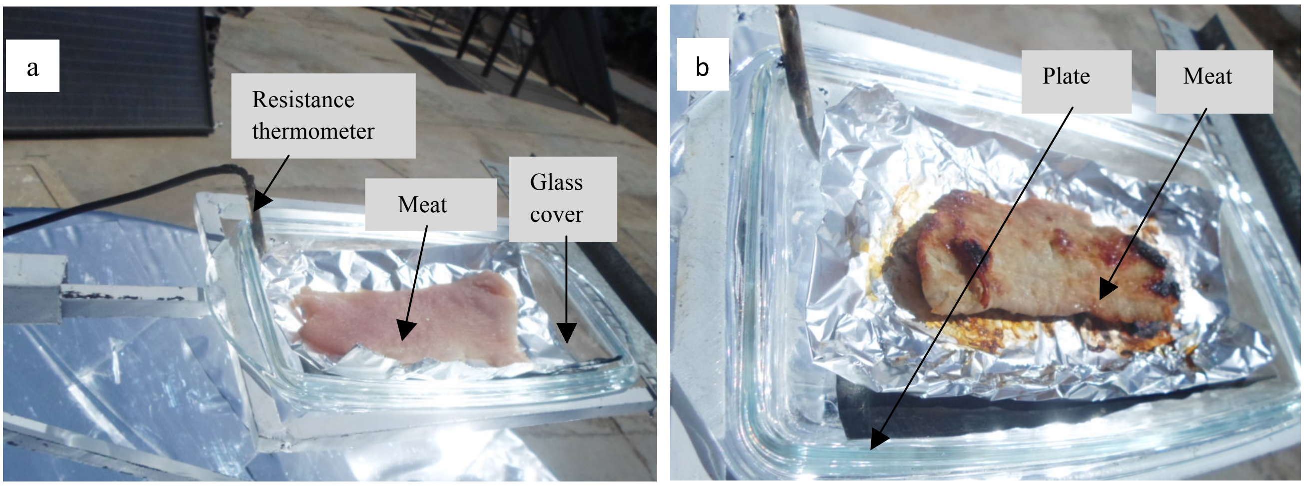

Figure 6: The receiver and the meat at the start of grilling (a) and at the end of grilling test (b).

4.2. Water boiling

In this section, the simulations were conducted to predict the temperature profile of water using the model developed for the process of water boiling. First, the proposed model was used to simulate a solar cooker which was studied experimentally by others researchers. The results of simulations were compared with the experimental measurements. Then, the prototype of the solar cooker was simulated using the weather data provided by the meteorological station installed in the Tataouine region at the south of Tunisia [16].

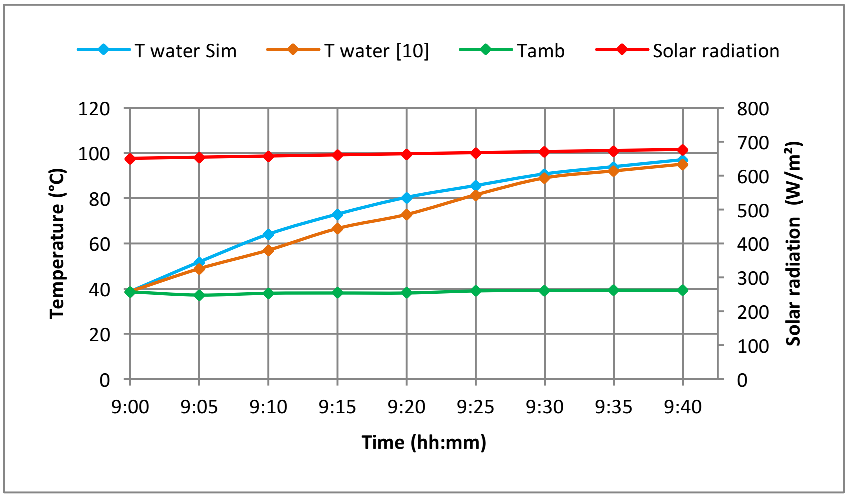

Figure 7: Comparison of the simulated water temperature and those of Gavisiddesha et al. [10].

The accuracy of the model is verified by a previously published experimental work carried out by Gavisiddesha et al. [10]. The settings of the parabolic solar cooker and the climatic conditions recorded during the experimental test are used in our simulations. The measured data and the simulated results are shown in Figure 7. The predicted values of the water temperature during the heating phase test are coherent with those obtained values by Gavisiddesha et al. [10].

The weather conditions of a summer day, plotted in Figure 8, were employed to simulate the process of water boiling using the solar cooker proposed in this study. The climatic data are given by the meteorological station installed in the south of Tunisia [16]. Figure 8 illustrates the variation of the solar radiation, ambient temperature and the wind speed during a summer day in Tunisia.

Simulation results of heating of 1 kg of water from 15°C to the boiling temperature are presented in Figure 9. The water reaches a temperature of 100°C which is the boiling temperature, after around 28 minutes. At this temperature, the treated water can be disinfected and the pathogens bacteria, the viruses and the parasites found in polluted water will be rapidly inactivated [3]. Boiling is the preferred thermal treatment to disinfect household water. The boiling of water using the concentrated solar energy could be practical in remote areas to partially disinfect naturally contaminated water available there. The presented solar cooker provides an important potential as a solution for the population that does not have access to clean water for drinking.

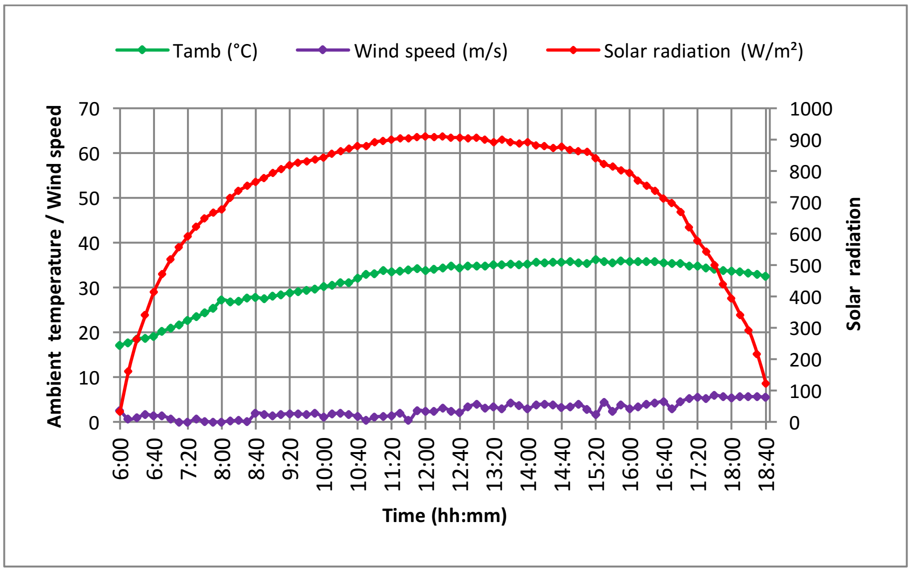

Figure 8: Solar radiation, ambient temperature and wind speed variations during a summer day in Tunisia.

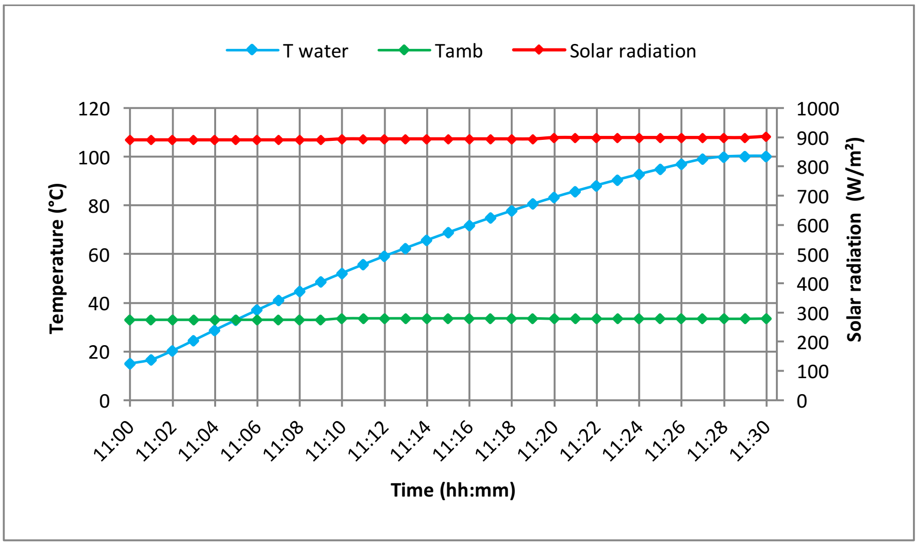

Figure 9: Variations of the temperature of water, ambient temperature and solar radiation during the heating test.

Table 3 summarizes the characteristics of the present proposed prototype and other designs of parabolic solar cooker reported in the literature. These solar cookers were used for water heating reaching a temperature of 95°C and 100°C in different conditions. The time required for heating water is mainly affected by the climatic conditions available in each location, the dimensions of solar cookers and also the materials used for the reflector and the receiver. These parameters affect the amount of the concentrated solar radiation at the receiver of the solar cooker and consequently affect the amount of the heat transferred to the water to be heated. Basing on the indicated aperture area, water amount and comparing the Abou-Ziyan [7] solar cooker performance, the present solar cooker gives an enhanced performance in terms of heating time for water to reach the boiling temperature.

Table 3: Comparison with others parabolic solar cooker.

Research	Aperture area (m^2)	Reflector material	Water mass (kg)	Heating time (min)	Temperature reached by water (°C)
Present study	1.13	Aluminum sheet	1	28	100
Abou-Ziyan [7]	1	Stainless steel	0.6	33	100
Gavisiddesha et al. [10]	1.54	Aluminum film	0.5	40	95.15
Arenas [9]	0.78	Film of metallised polypropylene	1.5	90	95
Aidan [11]	1.22	Aluminum sheet	0.37	40	95

4.3. Fuel savings and environmental impact

In Tunisia, natural gas, propane gas and butane gas are the main sources of energy used for cooking in the urban areas. In the countryside areas of Tunisia, wood and coal are used as an energy source for cooking. The climate of Tunisia is characterized by a high level of solar potential [16]. The use of solar cookers can reduce the consumption of the conventional fuels and the amount of CO_2 emissions.

The intensity of direct normal irradiation (DNI) is suitable for solar cooking when it exceed the value of 600 W/m^2.The monthly distribution of number of days with intensity of DNI more than 600 W/m^2 during a typical year in Tunisia is represented in Figure 10. The DNI values are given by the meteorological station installed in the south of Tunisia [16]. There is 305 days having a DNI more than 600 W/m^2 during at least 3 successive hours for the typical presented year. The DNI exceed the value of 600 W/m^2 for all the days of summer months (June, July and August). During the seasons of spring (March and April) and the autumn (September, October and November) the number of days is also important and it can reaches 27 days for month. For the season of winter (December January and February), the number of day is higher than 20 days per month.

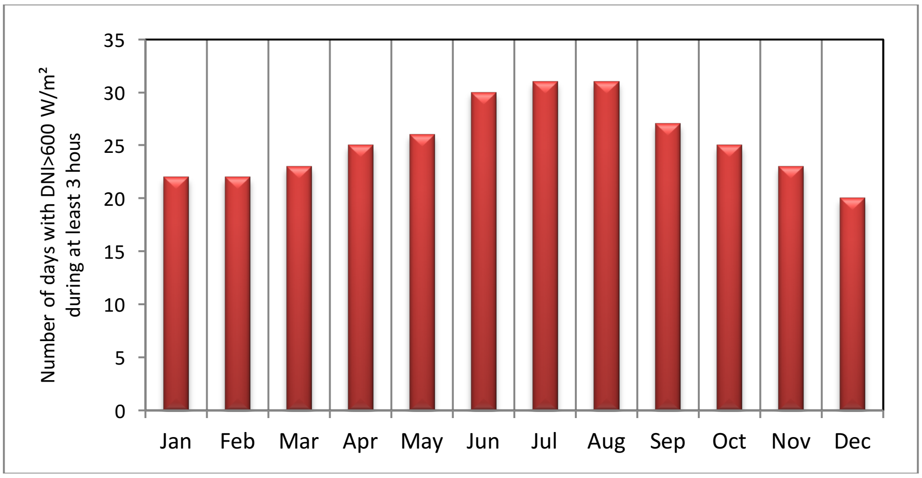

Figure 10: Monthly number of days with direct normal irradiation DNI>600 W/m^2 during at least 3 successive hours for a typical year in Tunisia.

The energy saved using the proposed solar cooker was estimated for conventional fuels such as natural gas, propane, butane, coal and wood for the typical presented year in Tunisia. The CO_2 emission reduction was also estimated for each type of fuels.

Considering a use of the solar cooker during 3 hours per day for a solar radiation of 600 w/m^2, the heat power provided is equal to 1.04 kWh. The solar cooker provides a heat power of around 317.63 kWh per year. The power scale of energy reached by the solar cooker is sufficient for cooking food [9], which reveals the ability of this solar cooker to cook in some remote areas like desert where the fuels needed for cooking are not available.

The coefficient of energy conversion given by RE-Emploi [23] are used to find the equivalent energy saved in term of natural gas, propane gas, butane gas, coal and wood and the corresponding avoided CO_2 emission. The yearly amount of conventional fuels saved and the corresponding CO_2 avoided by the use of the proposed solar cooker are summarized in Table 4. The use of the solar cooker is able to save a 127.05 kg per year of wood, which is used for cooking in rural areas, corresponding to an equivalent avoided CO_2 emission of 123.87 kg per year. If the solar cooker will be used by a large number of people, the amount of the wood saved will be very important and this can be a key item to contribute in reducing air pollution which occurs during wood combustion and deforestation caused by cutting of trees for fuel woods.

Table 4: Annual amount of conventional fuels saved and the corresponding CO_2 emissions reduction.

Conventional fuels	Amount of energy saved	Amount of CO_2 reduction (Kg)
Natural gas	31.39 m^3	64.16
Propane	48.20 L	70.83
Butane	25.01 kg	70.83
Coal	38.13 kg	106.40
Wood	127.05 kg	123.87

Conclusion

In this paper a parabolic solar cooker was designed, constructed, simulated and experimentally tested under the Tunisian climatic conditions. The solar cooker was proposed to provide food and disinfect water in rural and remote areas where there is no available energy resources. The main results reported in the present investigation are cited below.

- The results show that the plate used for cooking reaches a temperature more than 300°C in a fast time. The heated plate allows to grill the meat in an acceptable cooking time.
- The solar cooker is able to achieve the boiling temperature of water allowing the disinfection of household water.
- The solar cooker can produce a yearly thermal energy of around 317.63 kWh. The heat power reached by the cooker is sufficient for cooking food in remote areas that suffers from lack of cooking fuels. In addition, solar cooking can be adopted as an alternative way for cooking in rural areas where the wood is still used. The proposed solar cooker offers the opportunity to reduce the consumption of 127.05 kg of wood which corresponds to 123.87 kg of CO_2 emission during a year.
- The availability of sunlight conditions in Tunisia is suitable for using the proposed solar cooker. Solar energy can be a key item to meet the energy needs for cooking and water disinfection. The proposed solar cooker can help people in remote areas who doesn't access to conventional cooking fuels and clean water. Solar cooking can be considered as an interesting alternative solution to use in rural areas especially as an alternative to the fuel woods which contribute to fight against deforestation and air pollution.

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