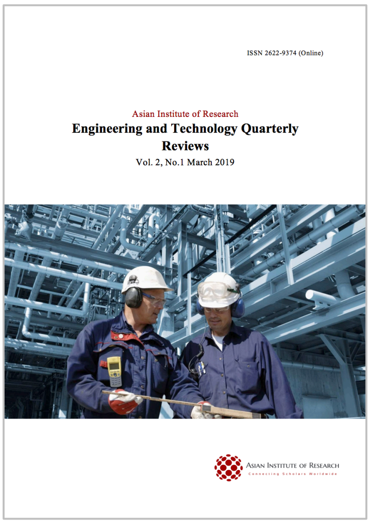

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Design and Construction of a Domestic Solar Cooker

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Abstract
Over the years, increase in energy demand has stirred up research interest aimed at harnessing the abundant energy from the sun to meet human's energy needs. One of such needs is feeding, and this is achieved through cooking. Most of the conventional cooking methods affect the ecological system negatively. Hence, the study aimed to design and construct a solar cooker. The solar cooker is made up of four main parts viz: the pot, the parabolic reflective dish, the bracket and the dish stand with its base. The selection of materials for the construction of the solar cooker is governed by material properties, local availability, the service condition and cost. The quantity of heat needed for cooking a 2.5 kg of beans, for 120 minutes and the lowest solar insolation value of Owerri city recorded in December as 33.19 MJ/m2/day were used as the criteria for the dish sizing to ensure effective performance all year round. As a result, the area of the solar dish was constructed to be 3.6 m2 with a diameter of 2.15 m and a focal length of 1.0 m. Results of the performance evaluation carried out on the solar cooker showed that at a solar insolation value of 412.15 W/m2, the cooking time for 2.5kg each of beans, rice, yam, and boiling of 2.5kg of water were 120, 93, 67, and 13 minutes respectively. The efficiency of the unit is relatively stable within slight changes in solar insolation; a 6% change in the solar intensity would only affect the efficiency of the solar cooker by 0.7%.The study noted that solar insolation value plays a major role in the performance of the solar cooker because increase in the solar insolation value increases the heating rate, thereby reducing the cooking time. This suggests that in areas of the country with more hours of sun light and higher solar insolation, the use of concentrated solar panels for cooking is a viable option during day time.

Key Words: Solar insolation (Owerri), Solar cooker, 2.5 kg of Beans, Efficiency

Introduction

Solar technologies are designed to harness the renewable energy from the sun to meet human energy needs. These technologies could either be passive or active depending on the way they capture, convert and distribute sunlight. Passive solar technologies involve systems that do not require moving parts to harness solar energy, rather depend on the orientation, geometry, and external elements/factors to efficiently control the heat it receives from the sun. Examples of passive solar technology include orienting a building to the sun, and adjustment of the windows so as to balance the energy requirements of the building in both summer and winter seasons. Active solar techniques involve the movement of photons, electrons or fluid to convert the trapped solar energy to useful forms [1]. They include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Photovoltaic systems harness solar energy for the production of electricity; concentrated solar power systems focus beams of reflected sun rays on an area to generate working fluid in steam turbines. Concentrated solar panels (CSP) could also be used for water heating and domestic cooking. When CSPs are used in this form, the system could be called a solar cooker. Solar cooker is a device that cooks using only sun energy in the form of solar heat, thus could save a significant amount of conventional fuel usage currently. Solar cooking is one of the simplest, safest, clean, environment friendly, and most convenient way to cook without consuming conventional fuels or heating up the kitchen. A major concern of today is the rapidly depleting non-renewable natural sources of energy due to increasing energy needs. For instance, in the rural areas of Nigeria, the use of firewood to cater for the cooking needs of families has led to trees been felled indiscriminately. This action exposes those areas to deforestation and increased rate of erosion. A domesticated application of this CSP technology would alleviate these attendant consequences of deforestation. Hence, this study aims at the design and construction of a domestic solar cooker as an alternative to cookers that use non-renewable sources of energy.

Solar Cooker Description

The cooker consists of four main parts viz: the pot, the parabolic reflective dish, the bracket and the dish stand with its base. The cooking pot together with the pot holder and the parabolic dish are mounted on the bracket, which is supported by the dish stand and the base. The parabolic dish is fixed to the bracket with a tilting mechanism to enable manual tracking of the sun. A silver-coated glass mirror is used to obtain a reflective surface for the parabolic dish. In order to maintain the curvature of the parabola, the mirror was cut into pieces of 25.4 mm × 25.4 mm chips. These mirror chips were glued onto the surface of the parabolic dish. The choice of the pot is of primary importance, it is painted black; a black surface absorbs all radiation that falls on it but reflects none[2]. The heat radiation that was reflected by the mirror is absorbed by the black plate placed at the focal point of the parabolic dish where the cooking takes place.

Material Selection

The selection of materials for the construction of the solar cooker is governed by material properties, local availability, suitability for the service condition and cost. The following materials were used to construct the solar cooker: Mild Steel, Silver polished mirror, Aluminium. Table 1 gives a summary of the materials selected for the various components of the solar cooker.

Table 1: Material Selection

S/N	Component Parts	Material Used	Reasons
1	Parabolic dish, Bracket, Dish stand, and Base.	Mild steel	Ductile and malleable. High tensile strength. Ease in welding.
2	Reflector	Glass mirror	High optical reflectance/heat transmittance.
3	Pot (Absorber plate)	Aluminium	Ductile and malleable. High resistance to corrosion. Good conductor of heat and food hygiene friendly.

Component Description and Design

The Parabolic Dish

The parabolic dish collects solar radiation over a large area and concentrates it onto a smaller area usually the focal point, where the pot containing the food is located. To develop sufficient quantity of heat required to meet the design requirements , the solar insolation of the environment was considered. Solar insolation is the amount of electromagnetic energy (solar radiation) incident on the surface of the earth. The solar insolation is the amount of sunlight incident on a square meter of an environment per day. This knowledge was used to determine the size of solar collector required and the energy output.

Solar Dish Sizing

The solar cooker is required to cook beans meal of 2.5 kg by mass at a maximum cooking time of 120 minutes. The temperature at which beans would be cooked and deemed fit to be served is 102 ^oC [4]. Equation 1 gives the relation used to determine the quantity of heat needed to cook the beans.

$$Q = M_b C_b(\Theta_f - \Theta_i) + M_w C_w(\Theta_f - \Theta_i) + M_v L_v \quad (1)$$

where:

Mass of beans, (M_b)	2.5 kg
Mass of water,(M_w)	6.25 kg
Mass of water vapourized, (M_v)	3.5 kg
Latent heat of vapourization, L_v	2260 kJ/kg
Specific heat capacity of beans,(C_b)	3.68 kJ/kg ^oC
Specific heat capacity of water,(C_w)	4.186 kJ/kg ^oC
Initial temperature of the mixture,(Θ_i)	28^oC
Final temperature of the mixture,(Θ_f)	102^oC

Substituting the values, we get:

$$Q = (2.5\times3.68\times74) + (6.25\times4.186\times74) + (3.5\times2260) = 10526 \text{ kJ}$$

To achieve this quantity of heat, the solar dish area is determined using the lowest mean value of Owerri solar insolation recorded as 33.19 MJ/m^2/day [3]. This solar insolation value of 33.19 MJ/m^2/day implies that 406.59 J of solar energy falls on a square meter surface in Owerri per second or 1 m^2 of Owerri receives 406.59 W of solar power. The solar power needed to generate a heat of 10526 kJ in 120 minutes is therefore 1462.06 W. To determine the area, A_s required to trap 10526kJ of heat, Equation 2 is employed.

$$A_s = \frac{Required\ solar\ power\ (W)}{Solar\ insolation\ (W/m^2)} \quad (2)$$

$$A_s = \frac{1462.06}{406.59} = 3.6\ m^2$$

The diameter (D) corresponding to the cross sectional area of the solar cooker dish is determined using Equation 3.

$$D = \sqrt{\frac{4A_s}{\pi}} \quad (3)$$

$$D = \sqrt{\frac{4\times3.6}{\pi}} = 2.14\ m$$

The radiations incident on the dish are reflected (converged) to a focal point f and this is where the cooking pot would be located. The focal point (f) is determined with Equation 4.

$$f = \frac{D^2}{16h} \quad (4)$$

Where D = diameter of dish, and h = height of dish.

Based on the geometry of the dish, a dish height, h of 0.28 m is selected.

$$f = \frac{D^2}{16h} = \frac{2.14^2}{16\times0.28} = 1.0\ m$$

The orthographic drawing of the parabolic dish is shown in figure 1.

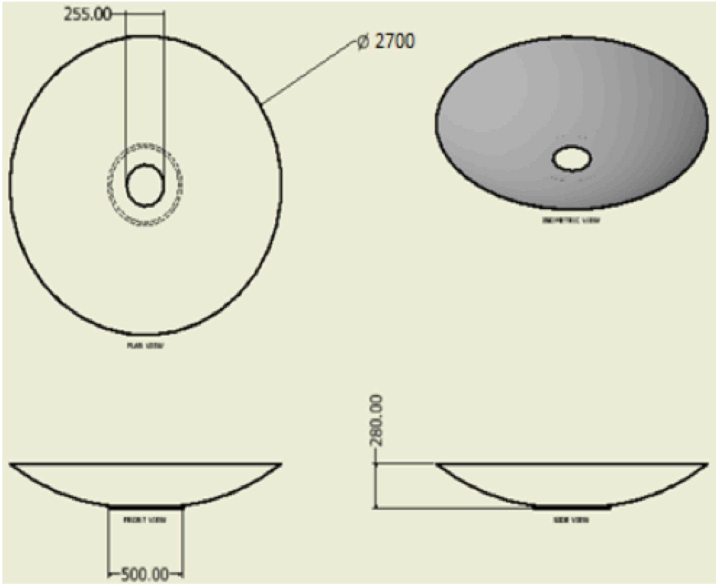

Figure 1: Orthographic projection of the parabolic dish.

According to [3], the monthly mean extra-terrestrial solar radiation on horizontal surface in Owerri varies from January to December. The lowest mean value is recorded in December; 33.19 $MJ/m^2/day$. This value was chosen in sizing the solar dish to ensure effective performance all year round.

Bracket

The bracket provides the means of hinging the dish on the stand so that it could be tilted freely towards the direction of the sun, to enhance manual sun tracking. Figure 2 shows the orthographic drawing of the bracket.

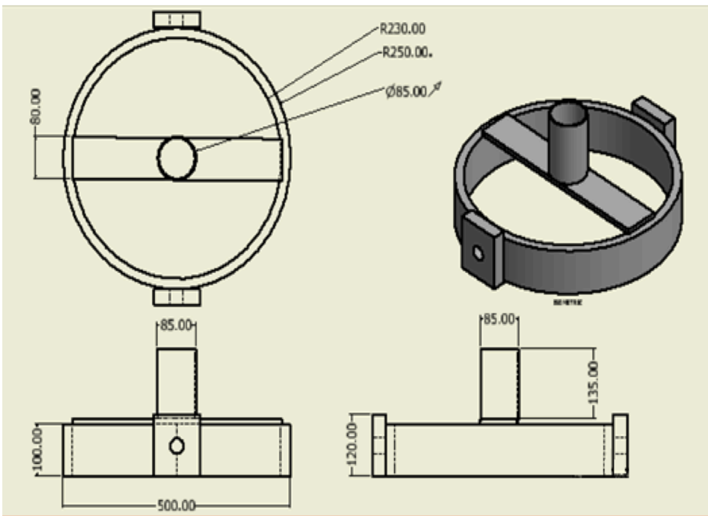

Figure 2: Orthographic projection of the bracket.

Dish stand

The dish stand provides support for the dish and connects it to the base. It is welded rigidly to the base, it is designed to have a total length of 625 mm with a diameter of 90 mm. The length of the stand is designed to withstand the given load without failure. The stand is treated as a column under load.
According to Euler, the critical buckling load is given by Equation 5:

$$W_{cr} = \frac{C\pi^2 EI}{L_e^{\ 2}} \quad (5)$$

C = Constant, representing the end conditions of thr column or end fixity coefficient = 4 when both ends are fixed [5].
E = Modulus of ridgidity of the colum material
I = Moment of inertia of the cross section.
L = equivalent length of the shaft.

But, for a column with both ends hinged the equivalent length (L) is equal to $l/2$ (Khurmi and Gupta, 2010). Therefore, from equation (6)

$$l/2 = \sqrt{\frac{\pi^2 EI}{W_{cr}}} \quad (6)$$

Where $W_{cr} = W$ =the crippling load which is taken as the load applied on the shaft.
The total load applied on the shaftW_{cr} is given by Equation 7:

$$W = M_d + M_p + M_{ps} + M_{fw} \quad (7)$$

Where,
M_d = mass of dish, M_p = mass of pot, M_{ps} = mass of pot stand, M_{fw} = Mass of food and water

Calculating the masses;

For mass of dish, M_d
$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Therefore, mass = density×volume

But volume of a parabola,
$$v = \frac{\pi}{2} h r_o^{\ 2} - r_i^{\ 2}$$

Where thickness of the dish = 1mm
r_o = outer radius of the dish = 0.915m
r_i = inner radius of the dish = 0.915m − 1×10^{−3}m = 0.914m
$$v = \frac{3.142}{2} \times 0.28 \times 0.915^2 - 0.914^2$$
$$v = 8.045 \times 10^{-4} m^3$$

Density of mild steel = 7850 kg/m^3[6]
Therefore mass of the dish $= 7850 \times 8.045 \times 10^{-4} = 6.32$kg
Weight of dish $= 6.32 \times 9.81 = 61.95$N
For mass of the pot stand, M_{ps}
mass = density×volume
volume of the shaft = A×L
L = length of the pot stand = 750mm
where A = area of the shaft $\frac{\pi d_o^{\ 2} - d_i^{\ 2}}{4}$
d_o = outer diameter of the shaft (m) = 30mm

$\mathrm{d_i}$ = inner diameter of the shaft = 20mm

Therefore,

$$A = \frac{3.142 \times 0.03^2 - 0.02^2}{4} = 3.9275 \times 10^{-4} \mathrm{m}^2$$

volume = $0.750 \times 3.9275 \times 10^{-4} = 2.945 \times 10^{-4} \mathrm{m}^3$

mass of the pot stand = $7850 \times 2.945 \times 10^{-4} = 2.31\mathrm{kg}$

weight of the pot stand = $2.31 \times 9.81 = 22.6\mathrm{N}$

For mass of the pot, M_p

Mass of pot = 1.8 kg, therefore weight of pot = 1.8 × 9.81

For mass of food and water, M_{fw}

Mass of food measured on scale 2.5kg and mass of water used in cooking= 6.5kg.

Therefore total mass= $2.5 + 6.25 = 8.75\mathrm{kg}$

Weight $8.75 \times 9.81 = 85.83\mathrm{N}$

Total weight/load on the shaft,

$$W = (61.95 + 22.6 + 17.66 + 85.83)\mathrm{N} = 188.13\mathrm{N}$$

Recall from $l/2 = \sqrt{\frac{\pi^2 EI}{W}}$

E = 200 GPa [6]

I = moment of inertia of the cross section $= \frac{\pi(D^4 - d^4)}{64}$

Where,

D = outer diameter of the shaft = 90mm

d = inner diameter of the shaft = 80mm

$$I = \frac{3.142 \times (0.09^4 - 0.08^4)}{64}$$

$I = 1.21 \times 10^{-6} \mathrm{m}^4$

Substituting the values from W_{cr}, E and I into equation (5); we get:

$$l = 2\left[\sqrt{\frac{3.142^2 \times 200 \times 10^6 \times 1.21 \times 10^{-6}}{188.13\mathrm{N}}}\right]$$

$$l = 4.0\mathrm{m}$$

This implies that the shaft will buckle under the applied load if the length is 4.0m; every other length below this is safe. Hence, 0.625m was chosen to enable for easy removal of the pot from the dish and to suit a wide range of operator heights.

Buckling analysis was run on the chosen length to ensure that the weight it carries does not exceed the critical buckling load limit of the dish stand material. From Equation 5, we get the critical buckling load of the dish stand to be:

$$W_{cr} = \frac{4 \times 3.142^2 \times 200 \times 10^9 \times 1.21 \times 10^{-6}}{0.625^2} = 24.46\ \mathrm{MN}$$

Also, the crushing stress the dish stand is subjected to as a result of the weight it carries is given as:

$$\sigma_{cr} = \frac{W}{A}$$

But A = area of the cross section $= \frac{\pi D^2 - d^2}{4}$ where,

D = Outer diameter of the shaft = 90 mm

d = inner diameter of the shaft = 80 mm

$$A = \frac{3.142 \times (0.09^2 - 0.08^2)}{4} = 1.335 \times 10^{-3} m^2$$

Therefore, the crippling stress of the column/dish stand is $\sigma_{cr} = \frac{188.13}{1.335 \times 10^{-3}} = 140.92$ kPa

Since W <<<W_{cr}, and the value of the dish stand crippling stress is less than the crushing stress of mild steel (300 MPa [5]) the choice of 0.625m for the dish stand is safe and would not buckle under the weight of the dish and pot. The orthographic drawing of the dish stand is shown in figure 3.

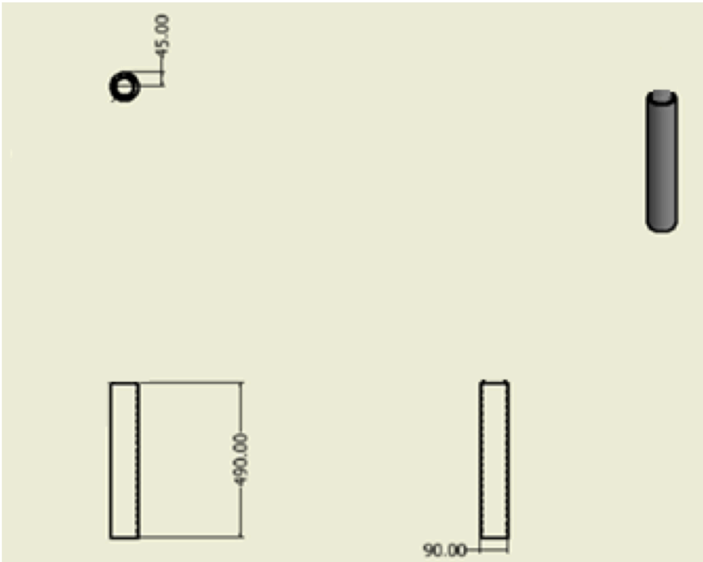

Figure 3: Orthographic view of the dish stand.

Base

A 9 mm thick mild steel angle iron was used for the base. The base carries and supports the components of the solar cooker. A square base of 700 mm was constructed.

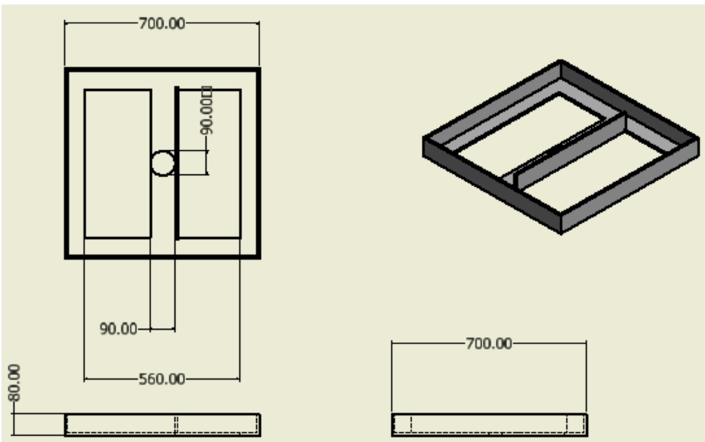

Figure 4: Orthographic view of the solar cooker base.

Figures 5a and 5b show the 3D model and the product prototype of the solar cooker respectively.

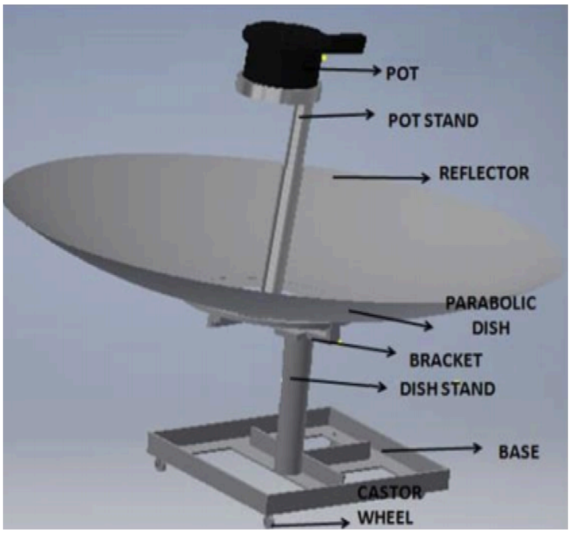

Figure 5a: 3D model of the domestic solar cooker.

Figure 5b: Product prototype of the domestic solar cooker.

Heat Losses

Heat Lost by Conduction

Equation 8 gives the heat loss by conduction,

$$Q = \frac{KA}{x}(\theta_f - \theta_i) \quad (8)$$

Where

$K = \text{Coefficient of thermal conductivity for mild steel} = 48.5\ W/m^2{}^\circ C$ [7]

The temperature of the pot is assumed to be in thermal equilibrium with the mixture

$x = \text{thickness of the pot} = 2mm$

And $A = \text{ surface area of the pot} = 2\pi(R^2 - r^2) + 2\pi(R - r)h$

where, $R = \text{Outer radius of the pot} = 0.120m$, $d = \text{inner radius of the pot} = 0.11965m$, $h = \text{height of the pot} = 0.165m$

Therefore,

$A = 2\times3.142\times(0.120^2 - 0.11965^2) + 2\times3.142(0.120 - 0.11965)\ \times0.165 = 8.90\times10^{-4}$

Therefore

$$Q = \frac{48.5\times8.90\times10^{-4}\times74}{2\times10^{-3}} = 1597J = 1.59kJ$$

Heat Lost by Convection

Equation (9) gives the heat lost by convection.

$$Q = H_C A\ (\theta_f - \theta_i) \quad (9)$$

$H_C = \text{Convection heat transfer coefficient}$
$= 28.5\ W/m^2{}^\circ C$

$Q = 28.5\times8.90\times10^{-4}\times74 = 1.8770J$

Heat Lost by Radiation

The heat lost by radiation is expressed in Equation 10 as:

$$Q = \sigma AT^4 \quad (10)$$

Where T= temperature of the solar cooker which is also assumed to be in thermal equilibrium with the mixture= $273 + 102 = 375$ K
σ =stefan boltzman contsant given as 5.67×10^{-8}
A= area of the solar cooker
$Q = 5.67\times10^{-8}\times2.86\times375^{4} = 3206.8\,J = 3.2\,kJ$

Heat loss as shown graphically in figure 6 is greatest by radiation, followed by conduction and convection.

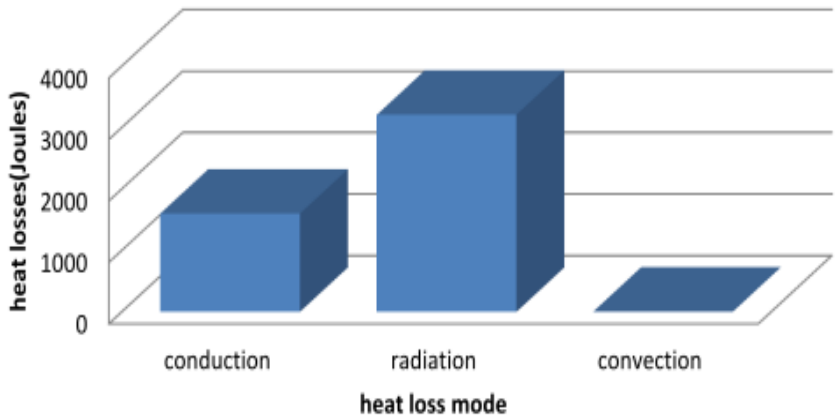

Figure 6: Heat losses across the solar cooker.

Performance Evaluation

After construction, the solar cooker was positioned in an open air space away from any form of sunlight hindrance/obstruction. The ambient temperature and solar insolation for each day when the performance test was carried out were measured using a thermometer and a solarimeter. 2.5kg of beans and 6.5 kg of water was placed in the pot. The probe of a digital thermometer was inserted in the pot in order to make contact with the food, enabling the cooking temperature to be recorded. The pot was then placed on the solar cooker pot stand for cooking to commence. The start time for cooking was recorded. Cooking temperature was monitored through the digital thermometer and changes in temperature values were recorded against corresponding changes in time. The monitoring time interval was 10 minutes, however, in cases where changes in temperature became gradual as the meal was about to get done, minute-by-minute recording of the corresponding cooking temperature was carried out. Therefore, from the start of the gradual change, a 2 minutes interval check was carried out in order to end the test just when the meal is done. The time at which this occurs is recorded as end time for cooking. The difference between the start and end time of cooking is recorded as the cooking time. Table 2 gives information on the variation of cooking temperature with respect to cooking time for the days the test was carried out.

Table 2: Observed values of cooking time against cooking temperature

Cooking Time (mins)	Cooking Temperature (^{o}C)				
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
0	28.34	28.31	28.33	28.32	28.38
10	36.56	40.43	40.67	43.02	40.45
20	46.56	52.67	52.32	55.78	52.51
30	56.34	63.32	63.45	65.42	62.08
40	66.67	74.56	73.90	78.71	75.59
50	76.89	81.47	79.56	83.17	79.31
60	86.21	91.87	83.98	90.30	88.56
70	90.34	92.43	89.92	95.07	92.78
80	93.77	93.75	94.67	98.59	96.53
90	94.34	94.66	98.53	100.72	98.93
110	96.67	95.12	100.78	102.01	100.05
115	98.89	97.19	102.56	102.03	101.01
116	100.01	100.45	102.55		102.61
118	101.34	102.64			102.64
120	102.39	102.62			
122	102.41				

Table 2 shows that the beans meal was cooked at an average temperature of 102.45°C and the temperature varies with increase in time. The cooking curves in figure 7 reveal that day 4 has the highest heating gradient than all the other days. This is also corroborated in Table 2 as it seen that it took a lesser time for the meal to cook in day 4 as compared to values obtained in other days.

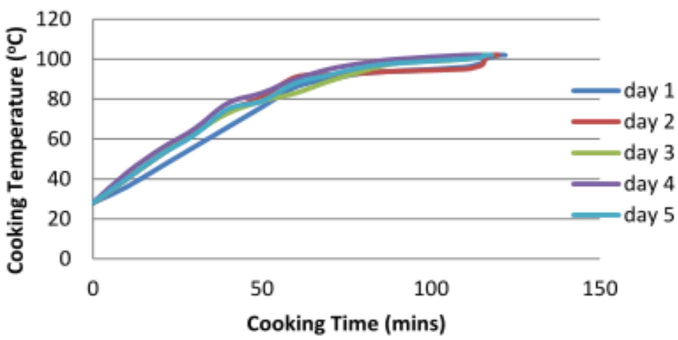

Figure 7: Graph of cooking temperature versus cooking time.

These observations can be explained with the information captured in Table 3. From the Table, it can be deduced that the solar insolation has an influence on the cooking time. This assertion is graphically illustrated in figure 8.

Table 3: Recorded values of ambient temperature, solar insolation and cooking time for various test days.

Test Day	Ambient Temperature ($^{\circ}$C)	Solar Insolation (W/m^{2})	Cooking Time (mins)
Day 1	33.29	406.59	122

Day 2	29.28	412.15	120
Day 3	29.37	428.82	116
Day 4	30.28	431.25	115
Day 5	31.02	418.75	118

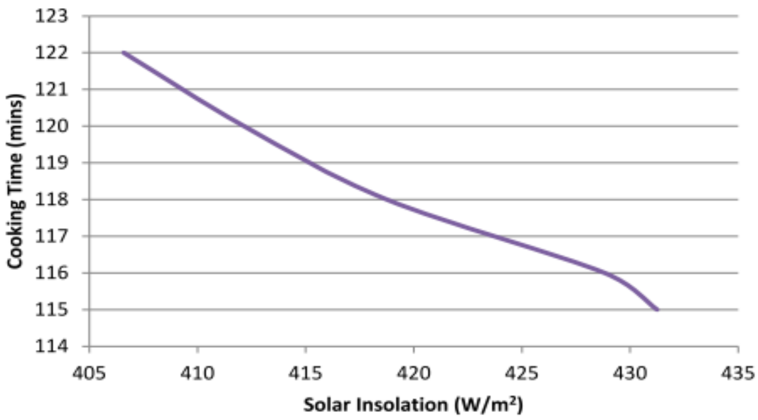

Figure 8: Graph of cooking time versus solar insolation

Figure 8 reveals that increase in the solar insolation would invariably, decrease the cooking time. This is expected because increase in solar intensity implies an increase in the amount of solar energy radiated to the pot, hence, an increase in the heating rate, and reduction in cooking time. Table 3 also shows that the differences between the cooking time for the various days is within a range of 1 to 7 minutes, corresponding to the variations obtained in values for solar insolation for the various days. In other words, slight variations observed in the solar insolation values are responsible for the slight differences in the cooking time for the various days.

Area Concentration Ratio

The area concentration ratio is the ratio of the area of the aperture to that of the receiver. The area of the aperture is determined by the area of the reflected light on the pot base. Equation 11 expresses the concentration area.

$$Area\ concentration\ ratio\ C_A = \frac{Area\ of\ aperture\ (A_p)}{Area\ of\ reciver\ (A_r)} \quad (11)$$

$$C_A = \frac{0.02}{3.6} = 0.005$$

Efficiency of the Solar Cooker

The efficiency of the system was evaluated using equation 12.

$$\eta = \frac{Q_{out}}{Q_{in}} = \frac{Q}{I_b A t} \quad (12)$$

Where:
Q_{out} = Q = Quantity of heat needed to cook the beans meal (J).
I_b = Solar insolation (W/m^2).
A = Cross sectional area of parabolic dish (m^2).
t = Cooking time (sec).
Table 4 shows the efficiency of the system for the days the test was carried out.

Table 4: Efficiency of the solar cooker for various test days.

Test Day	Ambient Temperature (°C)	Solar Insolation (W/m²)	Efficiency (η)
Day 1	33.29	406.59	0.987
Day 2	29.28	412.15	0.990
Day 3	29.37	428.82	0.984
Day 4	30.28	431.25	0.987
Day 5	31.02	418.75	0.991

From Table 4, it can be deduced that the solar cooker is stable in its operation since its highest percentage change in value is 0.7%.This implies that a 6% change in the solar intensity would only affect the efficiency of the solar cooker by 0.7%

Table 5 shows the result on the performance evaluation carried out for various food substances such as2.5kg of beans, 2.5 kg of rice,1.8kg of yam and 1 kg of water. The quantity of heat needed to cook each meal was calculated and thecooking timeof the meal was recorded.

Table 5: Cooking time for various meals using solar cooker.

S/N	Recorded Solar Insolation (W/m²)	Temperature (°C)	Meal	Quantity of Heat (kJ)	Cooking Time (Mins)
1	412.15	29	Beans	10526	120
2	412.15	29	Rice	3260.85	93
3	412.15	29	Yam	3618.64	67
4	412.15	29	Water	302.4	13 (Boiling Time)

The various meals cooked on the solar cooker was also cooked using different cooking medium like gas cooker, kerosene stove, firewood and comparisons were made.

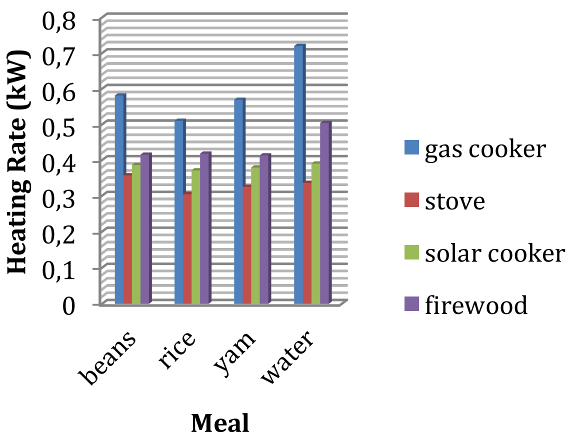

Figure 9: Graph showing the heating rate for various cooking medium

Figure 9 shows the comparison of the heating rate of the various cooking medium for rice, yam, beans and water.

From the four cooking medium, gas cooker has the highest heating rate and kerosene stove is the lowest. For firewood and solar cooker there's a slight difference in the heating rates, this suggests that on days when the solar intensity would be higher or in areas where there is higher solar intensity, there's a possibility that the heating rate of the solar cooker will be higher than that of the firewood.

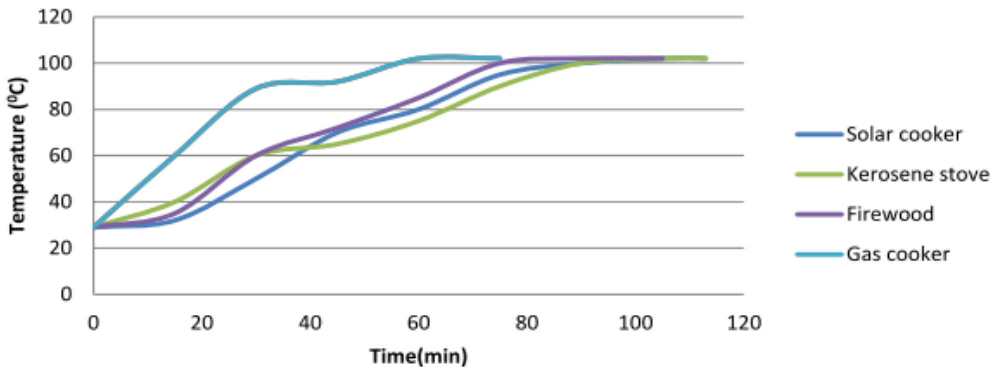

Figure 10: The variation of temperature against cooking time across the various cooking medium for beans

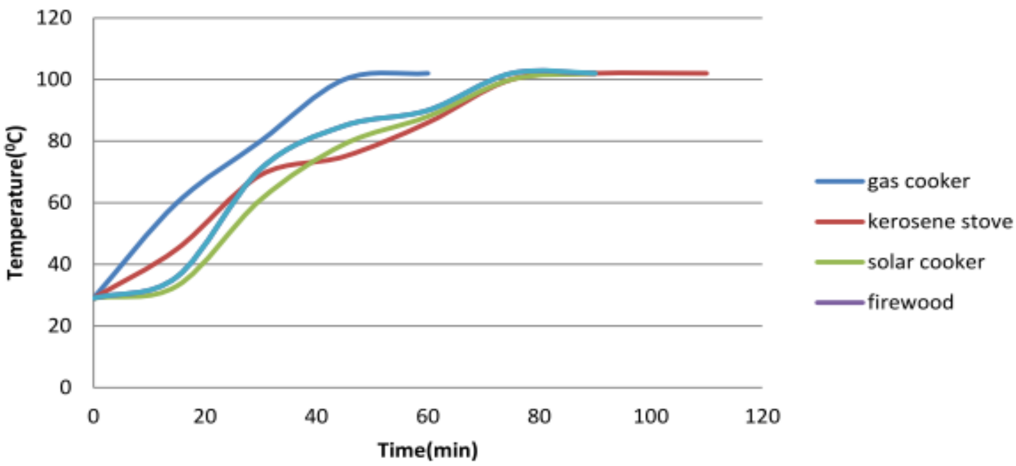

Figure 11: Variation of temperature against cooking time across different cooking medium for rice

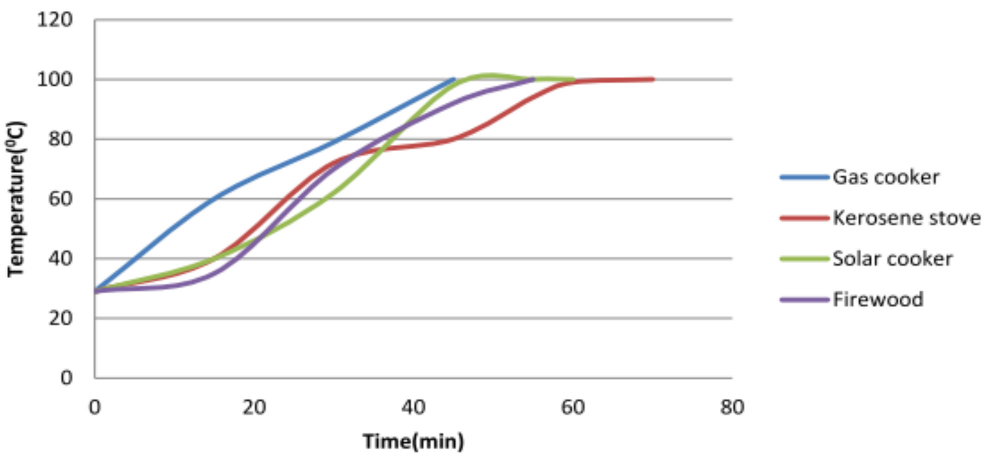

Figure 12: variation of temperature against cooking time across different cooking medium for yam

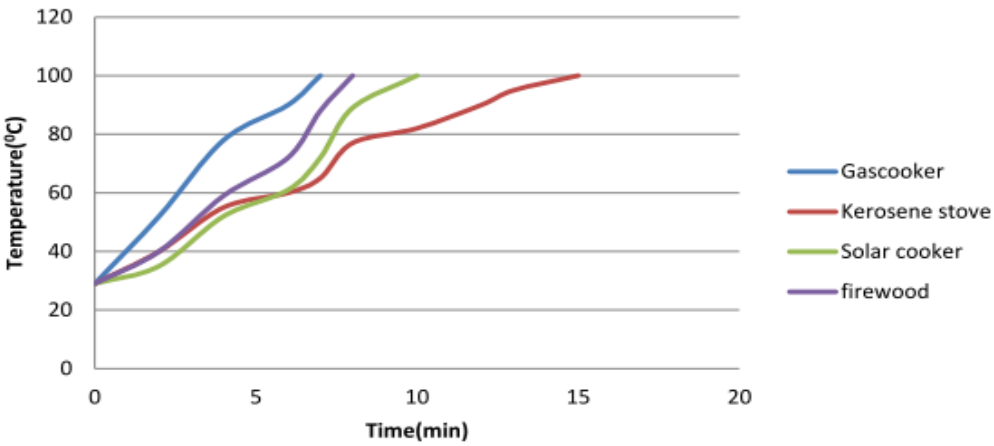

Figure 13: Variation of temperature against cooking time across different cooking medium for water.

Figures 10 to 13 show the variation of temperature against cooking time for beans, rice, yam and water across the various cooking medium. For all the meals, gas cooker and firewood take a shorter time than the solar cooker and the kerosene stove takes a longer time.

The firewood is slightly faster than the solar cooker because firewood undergoes uncontrolled combustion and solar insolation was not at its peak at the time of the year when the experiments were carried out. This suggests that in areas of the country with more hours of sun light and higher solar insolation, the use of CSP for cooking is a viable option.

Conclusion

The realization of this work provides potentially convenient alternative to conventional domestic ways of cooking; with their attendant negative effects on the environment – deforestation, erosion, emission of greenhouse gases. The test performance results obtained from the prototype of the solar cooker met the design requirements – the average cooking temperature of the beans was 102.45 ˚C compared with 102 ˚C from literature. The thermal efficiency was high and remained relatively stable within slight changes in the solar intensity. Places with higher solar insolation values would lead to portable designs and decreased cooking time exposure. A number of improved steps need to be taken in future designs and constructions of this particular case to minimize heat losses, maximize overall thermal efficiency and reduce component sizes.

References

1. http://www.solar-for-energy.com/active-solar-energy.html. Accessed 21/5/2018
2. Siegel R. and Howell J. R. 2002. Thermal Radiation Heat Transfer. Volume 1. 4 edition. Taylor and Francis.
3. Augustine, C and Nnabuchi, M.N. 2000. Analysis of some metrological data of some selected cities in the eastern and southern zone of Nigeria. *African Journal of Environmental Science and Technology.* 4 (2), 92 – 99.
4. Ihekoronye, A. I. and Ngoddy, P. O. 1985. Integrated Food Science and Technology for the Tropics, Macmillian Publishers, London.
5. Khurmi, R. S. and Gupta, J. K. 2010. A Textbook of Machine Design. Eurasia Publishing House (Pvt) Ltd., New Delhi India.
6. www.matweb.com/densityof mildsteel.html. Accessed 23/5/2018
7. www.farm.net/-mason/materials/thermal_conductivity.html. Accessed 21/5/2018