



## Application of Groundnut Oil as Thermal Energy Storage in a Solar Box Cooker for Enhanced Cooking Under Maiduguri Weather Condition

Maina, M. B., Abdulrahim, A. T., Shodiya, S.  
Department of Mechanical Engineering,  
Faculty of Engineering,  
University of Maiduguri, Nigeria

### ABSTRACT

The performance of Groundnut oil as phase change material (PCM) for thermal energy storage (TES) was investigated using a Solar Box Cooker (SBC) exposed to Maiduguri weather condition; Temperature and energy generated by SBC were experimentally established. The result shows tremendous improvement in energy storage compared to SBCs without TES in existence within Maiduguri and environs. The measured temperature and energy generated by the PCM in the experiment were 137°C and 307KJ respectively, an adequate temperature and energy stored by the PCM for cooking during off-sunshine hours. First figure of merit ( $F_1$ ) and second figure of merit ( $F_2$ ) were deduced to be 0.13 and 0.4 with overall SBC efficiency ( $\eta$ ) of 32% qualifying the SBC to grade 'A' based on the Bureau of Indian Standards (BIS).

### ARTICLE INFO

#### Article History

Received: August, 2019

Received in revised form: September, 2019

Accepted: December, 2019

Published online: December, 2019

### KEYWORDS

Solar Box Cooker, Phase Change Material, Thermal Energy Storage

### INTRODUCTION

With the rapid development in civilization, man has increasingly become dependent on natural resources to satisfy his needs. Cooking food is one of those indispensable processes that require natural resources in the form of fuels. Solar cooking is fast becoming a preferred method of cooking food considering the potential of saving significant amounts of conventional fuel. The major factor that limits the solar energy for cooking application is that it is a cyclic time dependent energy source. Therefore, solar systems require energy storage to provide energy during the night and overcast periods. In addition, one of the major requirements in using solar energy for cooking application is the development of a suitable cooking unit, which should be fast and energy efficient.

Over the last century, many studies have been performed on the development of various types of solar cookers and on the evaluation of the performance and economic aspects of solar cookers. There have also been several attempts to increase the performance and efficiency of cookers in non-tropical regions, Oturanc et al, (2002). Different types of solar cookers (Box type, direct or concentrating type and indirect type) were modified and investigated by researchers Elsebail et al., (2011). Some researchers have investigated the performance of a solar cooker for possible use in different applications, with modifications in outer-inner reflectors, Elsebail, (1997); different insulating

materials (Mishra et al, 1984 and Nahar, 2001), various booster mirrors (Mirdha and Dhariwal, 2008), absorber plate (Amer, 2003 and Harmim et al., 2010), a hybrid solar system (Prasanna and Umanand, 2011 and Nahar 1993) among several other modifications,

Recently, some studies have been performed concerning the use of phase change materials (PCMs) integrated with solar cookers as thermal energy storage (TES). The use of a PCM results in shorter cooking times, Sharma et al. (2005). It is concluded that, acetanilide is a promising PCM for cooking indoors with aluminum; but it exhibits some corrosion in contact with steel. However, magnesium nitrate hexahydrate is not stable during its thermal cycling due to the phase segregation problem; therefore, it is not recommended as a storage material inside solar cookers for cooking indoors (Elsebail et al, 2009). Also, these PCM are rather expensive when high temperatures are concerned. The ideal PCM to be used for latent heat storage system must meet following requirements: high sensitive heat capacity and heat of fusion, stable composition, high density and heat conductivity, chemical inert, non-toxic and non-inflammable, reasonable, and inexpensive, Sharma et al., (2009).

Several attempts were made to increase the performance and efficiency of solar cookers developed and tested in Maiduguri and environs, Ngala et al., (2015). Solar cookers are expected to

contribute considerably towards meeting the requirements of domestic cooking energy with 8-9 hours of sunshine hours in Maiduguri and environs, Maina et al., (2016). Despite the enormous solar energy potentials of Maiduguri solar cookers are not widely used

Groundnut oil is expressed from the seed of *Arachis hypogaea* L., commonly known as groundnut, peanut, or earth nut because the seeds develop underground, it has high smoke point of 229.4°C which allows food to cook fast with negligible oil absorption. It shall be used experimentally in this work as latent heat storage material i.e. thermal energy storage. Its physical properties is as presented in table 1.

Available literature shows that no investigation dealing with PCM use in solar cooker was carried out in the study area hence, this work intends to develop an experimental model of a solar box cooker with TES (Groundnut oil) a phase change material using the weather conditions of Maiduguri, This will also increase the reliability of the solar box cooker as it improves operational performance of the system to be used for off-peak periods. It is also an approach and or solution for bridging the gap between solar energy availability and demand, especially for cooking purposes in the study area (Maiduguri). The cooker for this study basically conforms to a box within a box with transparent double glazing and access door by the side as shown in fig 1.

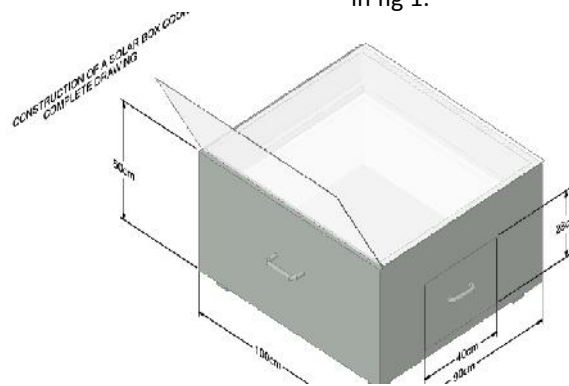


Fig 1: A double glazed Solar Box Cooker (SBC) with a booster mirror.

## MATERIALS AND METHODS

### Parts of the Solar Box Cooker

The box unit consists of a double walled box. The inner and outer boxes were made of plywood. The dimensions of the outer box are 100×90×50 cm and of the inner box are 88×78×35 cm. Kundapur (2009) suggested that the depth of

the inner box should not be more than 10-15 cm. The space between the two boxes was maintained at 6 cm and was filled with sawdust insulation obtained from local carpenters. The inner box was painted black for optimal heat absorption. The box was designed using Ansys Design Modeller as shown in figs. 2 and 3 respectively.

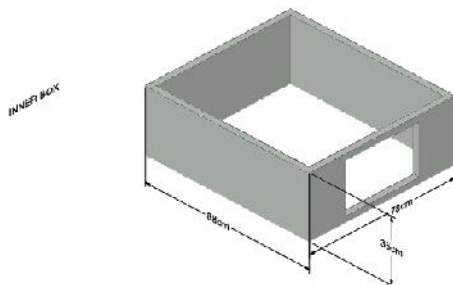


Fig. 2.: Inner Box

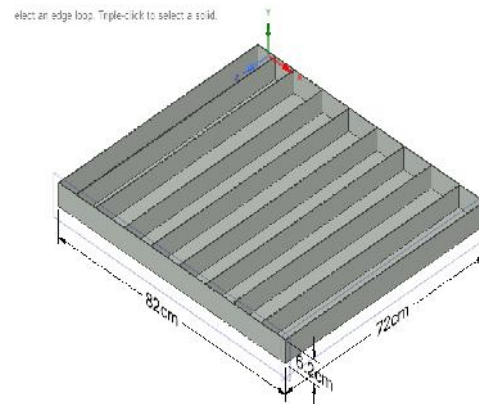


Fig. 3: Thermal Energy Storage Tank

Experimental tests were conducted after constructing physical model of the SBC as shown in fig 4 under various weather conditions to determine the viability of using Groundnut Oil as TES. To evaluate the performance of the solar box cooker in

Maiduguri the measured parameters include ambient temperature, solar irradiance, cooking chamber temperature, plate temperature, and PCM temperature.



Fig. 4: Box unit with PCM tank before and after glazing

### Design Considerations

The design parameters considered included the energy requirements, daily average insolation, and size of PCM container, ambient temperature and melting temperature of the PCM. The experimental temperature measurement was performed in selected points. At the wall surfaces: convective and radiative heat transfer conditions were applied to all outer walls and to the feeding glass (receiver). Heat flux to the wall was given as:

$$q = h_f (T_w - T_f) + q_{rad} \text{-----} 2.0$$

$h_f$  is the local heat transfer coefficient of air ( $w/m^2k$ ),  $t_w$  is the wall surface temperature (k),  $t_f$  is the local air temperature (k) and,  $q_{rad}$  is the radiative heat flux ( $w/m^2$ ). Air, which consists of nitrogen, oxygen, small amount of carbon dioxide and other gases, has been found not showing absorption band in those wavelength regions of importance to radiant heat transfer. The walls are insulated with Sawdust

Table 1: Thermo-physical properties of materials in use

Material	$\rho$ [kg/m <sup>3</sup> ]	$cp$ [J/kgK]	$\lambda$ [W/mK]	$\epsilon$	LHF(Kj/kgk)
plywood	850	1.250	0.150 0.8	-	-
Mirror1.	19	-	6.7	-	-
aluminum	2700	896	229	-	-
glass	2700	840	0.76	0.94	-
air	0.7	1034	0.037	-	-
Saw Dust	-	-	--	-	-
Groundnut Oil	920	2.000	-	3	21.7-

Source: Mishra et al. 1984

### METHODS

Tests were conducted under various weather conditions to determine the viability of using Groundnut Oil a phase change material (PCM) as TES, to evaluate the thermal performance of the solar box cooker in comparison with non-PCM box cooker used around Maiduguri environs. The measured parameters include temperature, solar irradiance and the wind speed. The performance tests of the SBC were done according to Bureau of Indian Standards, BIS (2000). All the measured parameters were recorded at intervals of ten

minutes. According to Funk (2000) ten minutes is long enough time that the minor fluctuations in heat loss due to ambient temperature and wind variability are expected to be negligible. The T-type thermocouples of Cu-Ni (Copper-Nickel) with temperature range of 185 °C to 300 °C was used to measure the temperature distribution inside the PCM storage unit, the temperature inside the cooking vessel, the absorber temperature and the ambient temperature.

### Thermal Performance Tests

#### Stagnation Test

A number of tests without load were conducted on the cooker to determine its stagnation temperature and also to check the rise in temperature inside the cooker. The stagnation temperature ( $T_s$ ), ambient temperature ( $T_a$ ) and absorber plate temperature ( $T_p$ ) were measured for different time of the day between 09:00 am and 4.00 pm during the operation of the cooker using 1.6mm diameter thermocouple with Elix digital thermometer (LX-6500) capable of reading temperature between  $-50^\circ\text{C}$  and  $350^\circ\text{C}$ . Thermo Anemometer (PROVA Instrument, AVM 01) was used to measure wind speed ( $v$ ) and solar radiation was measured using global radiation meter (GRM 100).

#### Full Load Test

The loading test was done by placing a water-filled cylindrical pot covered by a lid, in the cooker. The test was conducted for three days with 1.0 kg of water in the first day, 1.5 kg of water in the second day and 2.0 kg of water in the third day. Each test was carried out on a relatively sunny day between 9:00 am and 4:00pm daily. The absorber plate temperature ( $T_p$ ), ambient temperature ( $T_a$ ), Oven temperature ( $T_o$ ), water temperature ( $T_w$ ), solar radiation ( $H_s$ ) and PCM temperature were measured using the instrumentation described in section 2.3.2

#### Performance Measurement

The performance evaluation of the solar box cooker involve estimation of the following parameters: First figure of merit ( $F_1$ ), Second figure of merit ( $F_2$ ) and cooker's efficiency ( $\eta$ ).

#### First Figure of Merit

The first figure of merit ( $F_1$ ) of a solar box cooker is defined as the ratio of optical efficiency ( $\eta_o$ ) and the overall heat loss coefficient ( $U_l$ ), (Mohammed, 2000).

$$F_1 = \frac{\eta_o}{U_l} \dots\dots\dots 2.1$$

Experimentally,

$$F_1 = \frac{T_{ps} - T_{as}}{H_s} \dots\dots\dots 2.2$$

Where  $T_{ps}$ ,  $T_{as}$  and  $H_s$  are stagnation plate temperature, average ambient temperature and intensity of solar radiation respectively.

#### Second Figure of Merit

The second figure of merit ( $F_2$ ) is evaluated under full load condition and can be expressed by the expression given as follows:

$$F_2 = \frac{f_1 M_w C_w}{A t} \ln \left( 1 - \frac{1}{f_1} \left( \frac{T_{w1} - T_a}{H} \right) \right) / 1 - \frac{1}{f_1} \left( \frac{T_{w2} - T_a}{H} \right) \dots\dots\dots 2.3$$

Where  $F_1$  is first figure of merit ( $\text{Km}^2\text{w}^{-1}$ ),  $M_w$  is the mass of water as load (kg),  $C_w$  is the specific heat capacity of water ( $\text{J/kg}^\circ\text{C}$ ),  $T_a$  is the average ambient temperature ( $^\circ\text{C}$ ),  $H$  is the average solar radiation incident on the aperture of the cooker ( $\text{W/m}^2$ ),  $T_{w1}$  is the initial water temperature ( $^\circ\text{C}$ ),  $T_{w2}$  is the final water temperature ( $^\circ\text{C}$ ),  $A$  is the aperture area ( $\text{m}^2$ ) and  $t$  is the time difference between  $T_{w1}$  and  $T_{w2}$  (s).

In order to attain cooking temperature at the solidifying point of the PCM at discharging point the energy released by the PCM and the food should be equal to the energy loss from the cooker as given in equation 2.4 by Sharma et al., (2002).

$$Q_{PCM} = M_{PCM} [C_{PCM} (T_m - T_a) + L + C_{PCM} (T_{PCM} - T_m)] \dots\dots\dots 2.4$$

Where,

$Q_{PCM}$  is heat stored by PCM (KJ),  $M_{PCM}$  is mass of PCM (kg),  $C_{PCM}$  is specific heat of PCM ( $\text{Kj/kg}^\circ\text{C}$ ),  $T_m$  is melting temperature of PCM ( $^\circ\text{C}$ ),  $T_{PCM}$  is temperature of PCM at 4:00pm ( $^\circ\text{C}$ ) and  $L$  is latent heat of fusion of PCM ( $\text{KJ/Kg}$ )

#### Cooker Efficiency

The overall thermal efficiency of the solar box cooker is expressed mathematically as given by Kalogirou, (2014):

$$\eta = \frac{M_w C_w \Delta T}{I_{av} A_c \Delta t} \dots\dots\dots 2.5$$

Where  $\eta_u$  represents overall thermal efficiency of the solar cooker;  $M_w$ , mass of water (kg);  $C_w$ , Specific heat of water ( $\text{J/kg}^\circ\text{C}$ );  $\Delta T$ , temperature difference between the maximum temperature of the cooking fluid and the ambient air temperature;  $A_c$ , the aperture area ( $\text{m}^2$ ) of the cooker;  $\Delta t$ , time required to achieve the maximum temperature of the cooking fluid;  $I_{av}$ , the average solar intensity ( $\text{W/m}^2$ ) during time interval  $\Delta t$ .

### RESULTS AND DISCUSSION

Various test results as highlighted earlier are presented below graphically and discussed to

draw inferences for or against based on facts and figures established by the work. These include the stagnation test, the load test and the cooker efficiency test.

### Stagnation Temperature Tests

Figs. 3.1 and 3.2 show the results of stagnation temperature tests under no load condition for Groundnut Oil (PCM) TES solar box cooker, at the beginning of the temperature reading by 9:00am ambient temperature was recorded to be 31°C while oven temperature has rosed to 60°C with corresponding solar radiation of 825W/m<sup>2</sup> as shown in fig. 3.1 . Oven temperature was raised to 102°C after 7200 seconds (2hrs) by 11:00am. The oven temperature varies between 102°C and 115°C for almost 3hrs (11:00am to 1:45pm) and later dropped to 93°C at the end of the test by 4:00pm with declining insolation.

Fig. 3.2 reveals the variation in the solar

radiation and its effects on plate temperature in Groundnut oil PCM SBC. The maximum plate temperature attained during the test was 124°C by 12:45pm while plate temperature was stagnated between 101°C to 124°C from 10:30am to 4:00pm when the last temperature was recorded to be 105°C. An average plate temperature of 105.9°C was maintained throughout the test period. The average ambient temperature for the test day was 33°C being cloudy with intermittent rainfall (7<sup>th</sup> July, 2018).  $F_1$  was deduced based on Eqn. 2.1 and was found to be 0.13 this value qualifies the SBC as grade A Cooker in accordance with the criteria set by BIS. The plate thermal behavior shows that heat loss from absorber plate of the SBC was minimal (stagnating at over 101°C from 10:30am to 4:00pm) and the absorber plate temperature increases irrespective of the fluctuations in solar radiation due to cloud cover, the findings are similar to the work of Mohammed et al (2013)

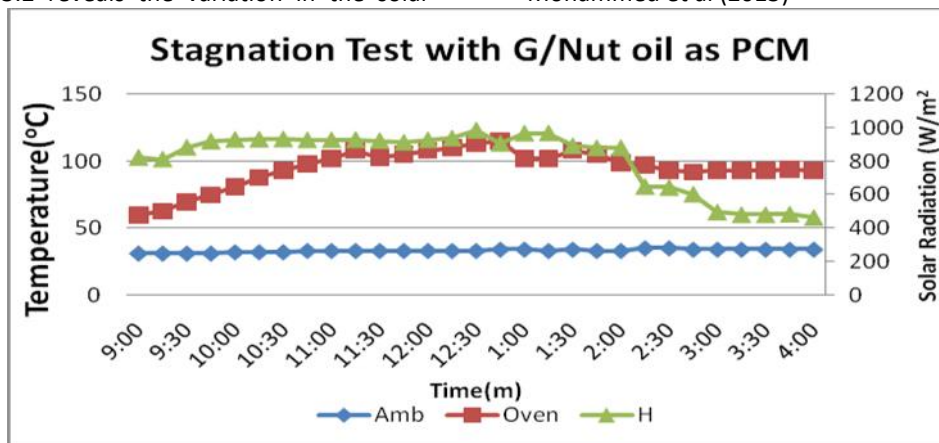


Fig. 3.1: Thermal performance curve in a SBC with Groundnut oil as TES under no load condition in a test day showing ambient and oven temperature against corresponding solar radiation

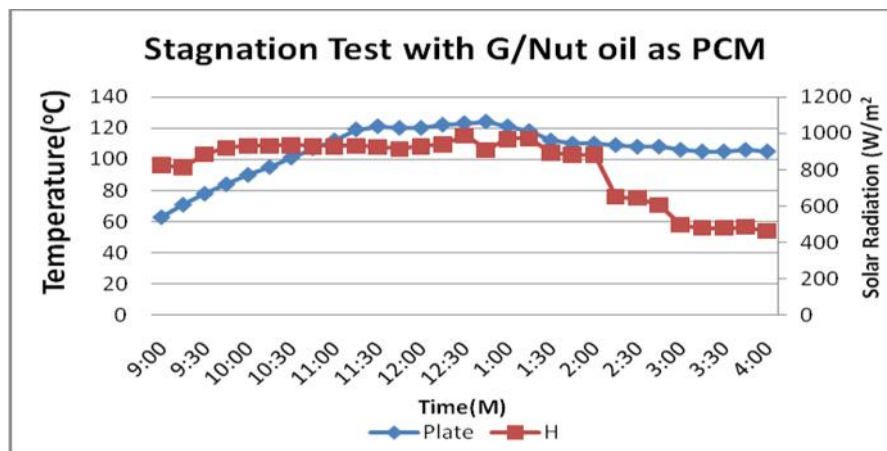


Fig. 3.2: Thermal performance curve of plate temperature in SBC with Groundnut Oil as TES in a test day

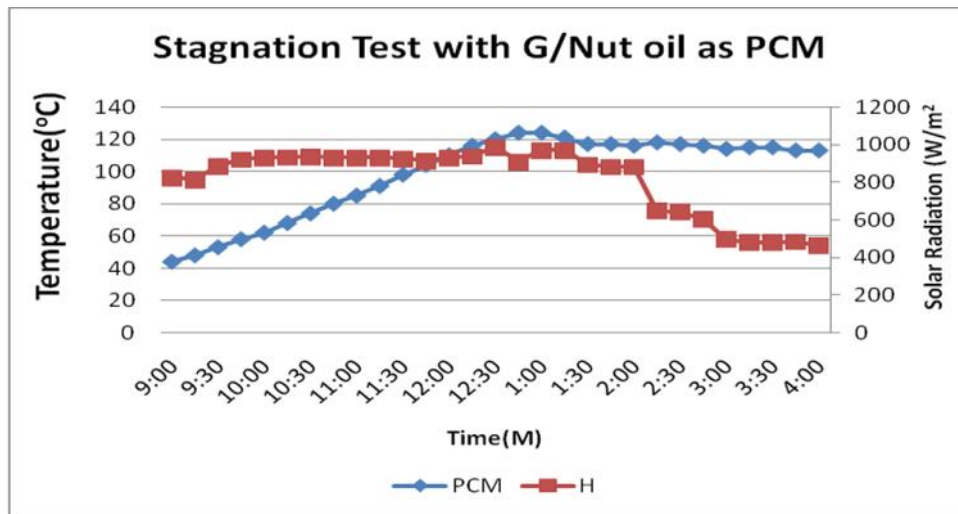


Fig. 3.3: Thermal performance curve of PCM (Groundnut Oil) temperature in SBC as TES in a test day

**Full Load Test (Boiling Test)**

The Groundnut PCM Solar box cooker under full load (1kg water) condition was able to provide a hot environment adequate for cooking most food items and maintaining its hotness/warmness for long hours after completion of boiling as shown in Fig. 3.4. The highest oven temperature of 132°C was attained by the box cooker at 1:30pm with corresponding insolation of 888W/m<sup>2</sup> and maximum plate temperature of 125°C with corresponding solar insolation of 891W/m<sup>2</sup> at 12:30pm as shown in Fig. 3.5. Plate temperature was raised to 101°C from 10:30am and the temperature was maintained above 100°C up to the end of the test by 4:00pm

when 118°C was recorded while an average plate temperature of 111.5°C was maintained throughout the test period.

The maximum temperature attained by the PCM (Groundnut oil) at 2:45 was 142°C showing appreciable heat storage with declining solar radiation (707W/m<sup>2</sup>). The amount of energy stored by the PCM (Groundnut oil) was determined based on Eqn. 2.4 and was found to be 307 KJ showing that the Cooker can also be used to get other food items cooked through the night at off Sun-shine hours under the prevailing weather conditions. Accordingly, the overall SBC energy efficiency was found to be 32% using Eqn. 2.5

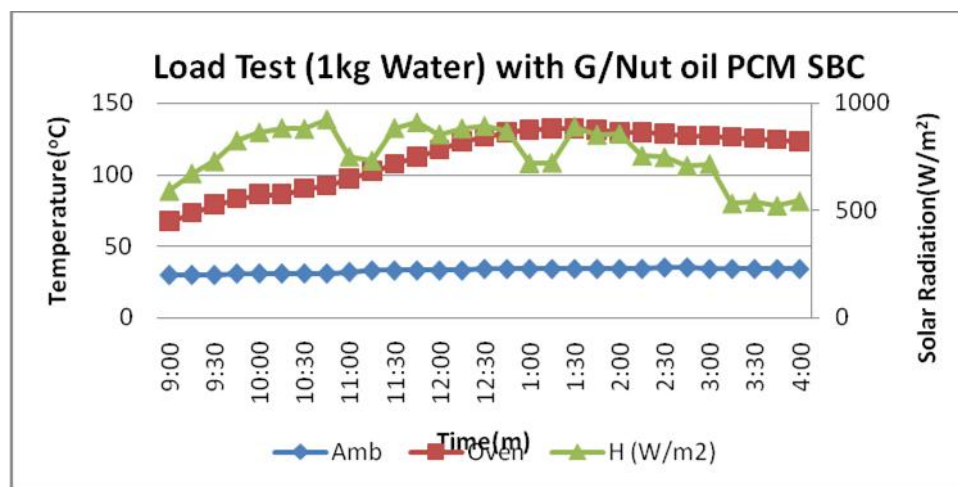


Fig. 3.4: Full load test with 1 kg of water in a SBC with Groundnut Oil as thermal energy storage showing ambient and oven temperatures against corresponding solar radiation in a test day

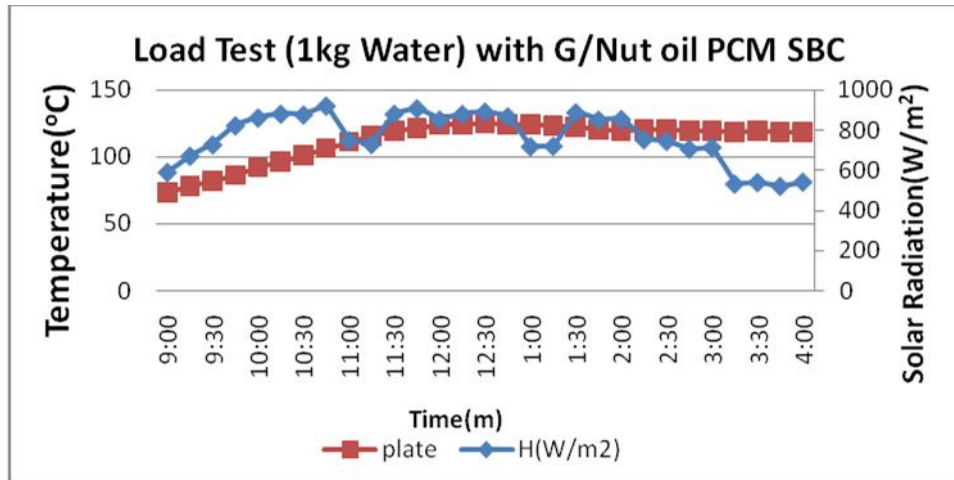


Fig. 3.5: Full load test in a SBC with Wax as TES showing plate temperature behavior with corresponding solar radiation in a test day

Heat transfer performance of Groundnut oil PCM during charging process with 1kg of water in the SBC is presented in fig 3.6, temperature variations inside the (PCM) with time as recorded shows no loss of heat despite dwindling Solar radiation observed on the test day (10<sup>th</sup> July, 2018).

PCM temperature was raised to 107°C by 11:00am and maintained to the end of the test (4:00pm) to 101°C with an average insolation of 767W/m<sup>2</sup> on the test day. The PCM charging behavior has shown good characteristics of recyclability with the temperature recorded at the end of the test.

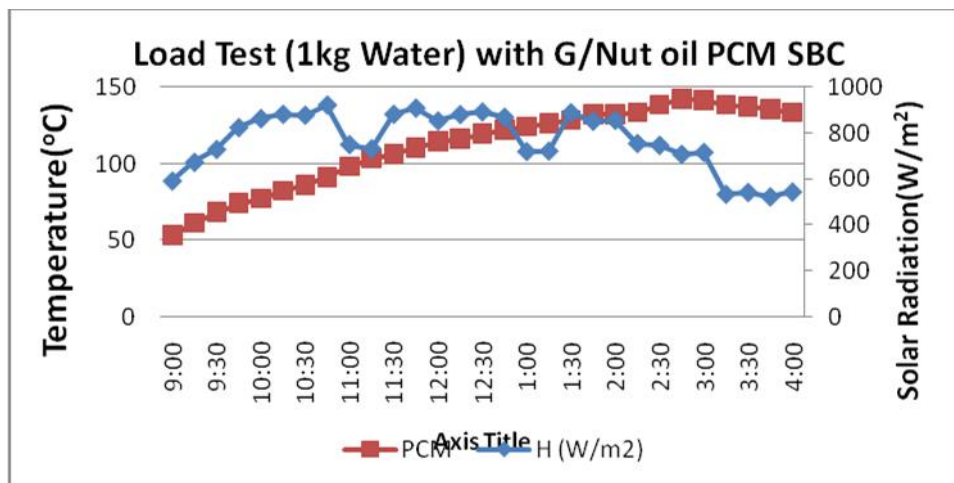


Fig. 3.6: Full load test in a SBC showing Groundnut Oil (PCM) temperature behavior with corresponding solar radiation in a test day.

The maximum pot temperature during the water boiling test with Groundnut oil PCM SBC shown in fig 3.7 was recorded to be 99.1°C attained by 12:45pm at a corresponding insolation of 868 W/m<sup>2</sup> while  $F_2$  was found to be 0.4 using Eqn. 2.3 which equals the minimum value of 0.4 set by BIS as grade "A" cooker for proper assessment of SBCs. The standard error of mean of pot temperature in the

Groundnut Oil PCM SBC was obtained as 3.60354 with standard deviation of 19.40504 for an average pot temperature of 84.5103°C, where as the oven, plate and PCM errors of mean were 3.86363, 2.86246 and 4.92380 respectively and their corresponding standard deviations were also deduced to be 20.80628, 15.41481 and 26.51549 respectively.

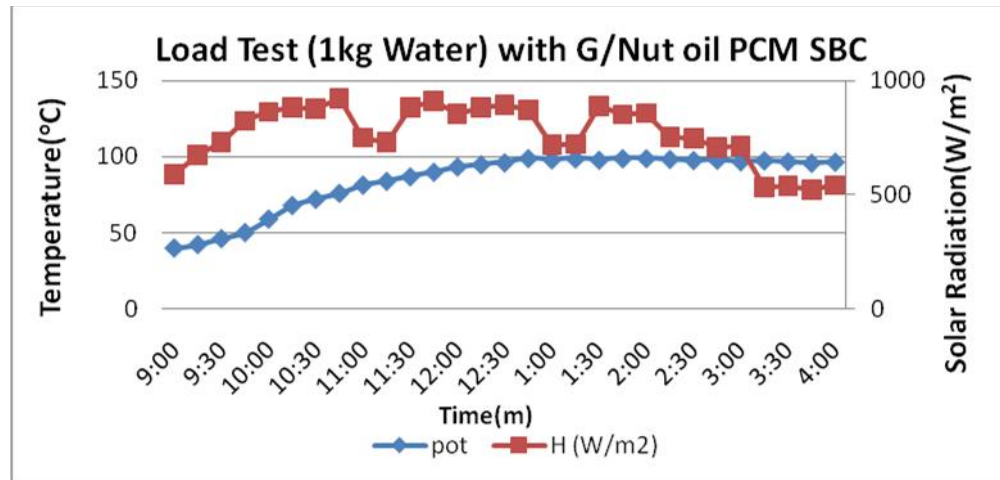


Fig. 3.7: Thermal curve of Pot temperature in a SBC with Wax as TES.

## CONCLUSION

In this study, Box type solar cooker with single booster reflector has been designed using Ansys 19.0, constructed, and experimentally tested under the weather conditions of Maiduguri. For the first time, the characteristics of Groundnut Oil as a PCM in Solar Box Cooker were investigated within the study area. Experiments were performed and the influences of different components were investigated, Groundnut Oil was found to store adequate energy (307KJ) for off peak period with 32% efficiency. From the experimental results of the solar box cooker the following conclusions were drawn:

1. The thermal efficiency of the solar cooker and the cooking times are found to depend strongly on the PCM, the reflector, insulation, and the solar intensity.
2. Groundnut Oil can be used as storage medium integrated with a Solar Box Cooker using Maiduguri weather conditions.
3. It is obvious that the total Solar radiation on cloudy days is lower than that of the clear days; the solar cooker receives reflected radiation from only a single reflector hence there is a possibility that high temperatures can be achieved by increasing the number of reflectors and incorporation of automatic tracking system for further optimization.
4. It is also expected that an improvement in the cooker performance is possible with the choice of a storage unit, a PCM and the amount of radiation received from the sun looking at the present findings despite the intermittent solar radiation due to weather conditions during the test period.

5. The use of thermal energy storage in solar cookers plays a pivotal role in a sustainable and enhanced energy management as well as for energy conservation.
6. Solar cooking has the potential to reduce fossil fuel use and the release of CO<sub>2</sub> to the environment

## REFERENCES

- Amer, E. H., (2003), Theoretical and Experimental Assessment of a Double Exposure Solar Cooker, *Energy Conversion and Management*, 44, 16, pp. 2651-2663
- Birds, R. B., Stewart, W. E. and Lightfoot, E. N. (2001), Transport Phenomena, John Wiley & sons, Inc. (2nd Ed.) New York
- Bureau of Indian Standards (BIS) IS 13429:2000.
- Domanski, R. El-sabaii, A. A. and Jaworsky, M. (1995), 'Cooking During Off-sunshine Hours Using PCM as Storage Media' *Energy*, 20, 7, Pp. 607-616
- El-Sebaii A. A, Al-Heniti, S. Al-Agel F.A.A., Al-Ghamdi F. and Al-Marzouki (2011), One Thousand Thermal Cycles of Magnesium Chloride Hexahydrate as a Promising PCM for Indoor Solar Cooking, *Energy Conversion and Management*, 52, 4, pp.1771-1777
- El-Sebaii, A. A., (1997), Thermal Performance of a Box-Type Solar Cooker with Outer-Inner Reflectors, *Energy*, 22, 10, pp. 969-978
- El-Sebaii, A. A. Al-Amir, S. Al-Marzouki, F. M. Faidah, A.S. Al-Ghamdi, A.A. and Al-Heniti, S... (2009) Fast Thermal Cycling of Acetanilide and Magnesium Chloride Hexahydrate for Indoor Solar cooking, *Energy Conversion and Management* 50(12) 3104–3111.





- Funk. A. (2000), Evaluating the international standard procedure for testing solar cookers and reporting performance, *Solar Energy*, Vol. 68, Issue1, pp. 1-7.
- Harmim, A., Merzouk, M. Boukar M. and. Amar, M (2010), Design and experimental testing of an innovative building-integrated box type solar cooker. *Solar Energy*, 98, 422-433.
- Kalogirou S. A. (2014) *Solar Energy Collectors*, Solar Energy Engineering (Second Edition), Chapter 3, Pages 125-220.
- Kundapur A. and Sudhir C.V. (2009) " proposal for new world standard for testing solar cookers" *journal of engineering science and technology*, 4 (3) pp 272-281
- Maina M.B, Ngala G.M and Abdulrahim A.T. (2016), Design, Fabrication and Performance evaluation of a Solar Brick Oven, *International Journal of Engineering Research & Technology*, 5, 1, Pp 176-182
- Mirdha, U. S. and Dhariwal, S. R., (2008), Design Optimisation of Solar Cooker, *Renewable Energy*, 33,3, pp. 530-544
- Mishra, R. S., Jai Sabberwal and Prakash, S. P., (1984), Evaluation of Solar Cooker Thermal Performance Using Different Insulating Materials, *International Journal of Energy Research*, 8 4, pp. 393-396
- Mohamed Ali BS. (2000), Design and testing of Sudanese solar box cooker. *Renewable Energy* 21:573–81.
- Mohammed, I. L., Ruma.U. J. and Abdulrahim. A. T., (2013), Performance testing of a Truncated Pyramid Solar Thermal Cooker, *Int. Journal of Engineering Research and Application*, 3, 4, pp.1174-1178
- Nahar, N. M., Design, (2001), Development and Testing of a Double Reflector Hot Box Solar Cooker with a Transparent Insulation Material, *Renewable Energy*, 23,2, pp. 167-179
- Nahar, N. M., (1993), Performance and Testing of Large-Size Solar Water Heater Cum Solar Cooker, *International Journal of Energy Research*, 17,1, pp. 57-67
- Ngala G. M., Maina M. B. and Tela M. B., (2015), Design and construction of a high concentration solar cooker, *International Journal of Research in Mechanical Engineering*, 3, 1, Pp. 01-07
- Oturanc, G., Necdet. O. and Gungor. A. (2002), Performance Analysis of a Solar Cooker in Turkey, *International Journal of Energy Research*, 26,2, pp. 105-111
- Prasanna, U. R. and Uman and, L.,(2011), Modeling and Design of a Solar Thermal System for Hybrid Cooking Application, *Applied Energy*, 88,5, pp. 1740-1755
- Sharma, A. Buddhi D. and Sharma S.,(2002), Accelerated Thermal Cycle Test of Acetamide Stearic Acid and Paraffin Wax for Solar Thermal Latent Heat Storage Applications, *Energy Conversion and Management*, 43: 14, pp. 1923-1930
- Sharma, A. Chen, C. Murty, V. and Shukla, A. (2009), Review on Thermal Energy Storage with Phase Change Materials and Applications, *Renewable and Sustainable Energy Reviews*, 13, 2, pp. 318-345
- Sharma, S. Buddhi, D. Sawhney R. and Sharma A.(2005), Thermal Performance of a Solar Cooker Based on an Evacuated Tube Solar Collector with a PCM Storage Unit, *Solar Energy*, 78 3, pp. 416-426
- Yuksel, N., and Avci, A.,( 2010), The Use of Solar Energy on the Cookers with Latent Heat Storage (in Turkish), *Proceedings*, 8th National Clean Energy Symposium, Bursa, Turkey, Pp. 23-31