PREPARATION OF PARAFFIN WAX SKIN TREATMENT USING A PARABOLIC SOLAR COOKER AS THE HEATING EQUIPMENT IN ILORIN KWARA STATE

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Abstract

A solar cooking system uses solar energies to heat and melt various substances, including paraffin. The solar cooker is a simple device that uses sunlight to cook food. The concept of solar cooking was introduced since in ancient times. Industrial heating and melting are an indispensable process in the manufacture of various organic products and household cooking. In order to provide a reliable method of heating and melting which is not hazardous to health and environment unlike the conventional sources, an alternative renewable energy was studied in this work which could also be used for industrial application. The aim of this work is to use parabolic solar cooking system to harness and focus solar radiation for heating and melting paraffin wax to prepare a solution for skin treatment under Kwara state metrological condition and also to measure various temperature parameters. The parabolic solar cooker was used in heating and melting paraffin wax with mineral oil as a lubricant. In the result obtained, the highest solar radiation was 1216.7w/m², the highest ambient temperature was 48.7˚C, the highest fluid temperature was 49.6˚C, the highest temperature of the cover was 59.6˚C, the highest side temperature was 56.4˚C, the highest absorber plate temperature was 94.6˚C and highest temperature of the air gap was 70.4˚C. The parabolic solar cooker was able to melt paraffin wax for 1hour, and the thermal performances in term of average cooking power, standard cooking power and cooker efficiency was evaluated.

Keywords: Parabolic Solar cookers, Paraffin Wax, Solar Radiation, Fluid.

Introduction

The sun is the main source of energy and its availability allows various ways to use free energy. One of the main applications of solar energy (often called solar energy) is solar heating technology (Ahmad, 2001), which comes in many different forms, from relatively cheap and technically simple to large and expensive that can be used for heating systems. Industrial heating. (Otte, 2013). A solar cooking system uses solar energies to heat and melt various substances, including paraffin (Solar Cooker International, 2001). The solar cooker is a simple device that uses sunlight to cook food. The concept of solar cooking was introduced in ancient times. The solar cooker was first constructed in 1767 by Swiss naturalist Horace de Saussure (the father of solar cooking) by building a small container in which he cooked fruit using only sunlight, reaching a temperature of 50.5°F. His experience opened the way for the world to further research. Around the world, many scientists and engineers are studying the production of modern and high-efficiency solar cooker models, and many organizations and renewable energy centers are working to spread and promote solar cookers in areas where they can work effectively. Box type, funnel type, panel type, parabolic type and vacuum tube technology (advanced type) are mainly five types of solar cookers used worldwide so far (Ahmad, 2001). Concentrated solar energy (CSP) is a technology for converting solar thermal energy into electricity or thermal energy (NUFU Network, 2013). There are many forms of using CSP as a heat source, but over the years parabolic concentrators have been shown to be the most efficient in terms of heat generation (Reddy and Ranjan, 2003).When used as solar cookers, they are also considered to be the fastest in terms of the time it takes to prepare food (Panwar et al., 2012).Solar cookers, particularly parabolic cookers, are seen as a potential solution to some of the challenges facing developing communities, such as over-reliance on inadequate electricity supply, leading to load loss, food insecurity, unemployment and rural exodus. other social problems (Bryceson, 1996; Von Braun, 2010). Heating is one of the basic activities that consume large amounts of fossil fuels. A solar cooker is an innovative way to use solar energy for heating and melting. One of the solar cookers used for cooking in recent times is the parabolic solar cooker, which essentially consists of an inexpensive, lightweight and highly reflective glass mirror that acts as a reflector. The solar energy obtained by using this solar cooker is enough to cook at home (Jayesh et al., 2013). The parabolic shape of the reflector allows the sun's rays to be concentrated on a small area that can reach very high temperatures. This concentrated heat is then used to melt the paraffin. The heating container can be a pot, pan or other container that conducts heat well and is suitable for heating and cooking (Aliyu et al., 2021). Parabolic solar cookers are often used in areas where access to electricity or other cooking fuels is limited, such as rural areas or developing countries. The Parabolic Solar Cookers are capable of melting wax quickly, often within minutes, depending on the intensity of the sunlight. They are also easy to use and require no fuel other than sunlight. Furthermore, they can be made from inexpensive and readily available materials (Craig, 2015). The goal of this project is to use a parabolic solar cooking system to harness and concentrate solar radiation to heat and melt paraffin to create a skin care solution.

Design and Construction

A parabolic solar cooker, which uses a parabolic dish as concentrator, was designed and developed. The parabolic solar cooker is made up of a parabolic dish the concentrator used was a television satellite dish whose diameter is 1.8m and its depth is 26cm, it was glazed by rectangular reflective glass mirrors with a thickness of 3mm. The arm of the parabolic dish is 1.1metres long and the parabolic dish has a flat metal base of 2cm thick. The height of the parabolic cooker was measured from the ground to the pot hanger as 0.6m.

Table 1:1 Design and Construction Measurement and Parameters

N/S	MEASUREMENT	PARAMETERS
1	Diameter	1.8m
2	Height	0.6m
3	Radius	0.9m
4	Area	0.26m
5	Aperture	0.016m
6	Concentrator	0.081m
7	Focal length	0.047m
8	Glass Thickness	0.3mm
9	Length	1.45m

Material

Selection of Materials

The Dish

The material used for the dish was steel, which was chosen over aluminum due to its strength, cost, durability and energy efficiency when using this material. Its smooth contour shape minimizes the tilt error of the reflective mirror material.

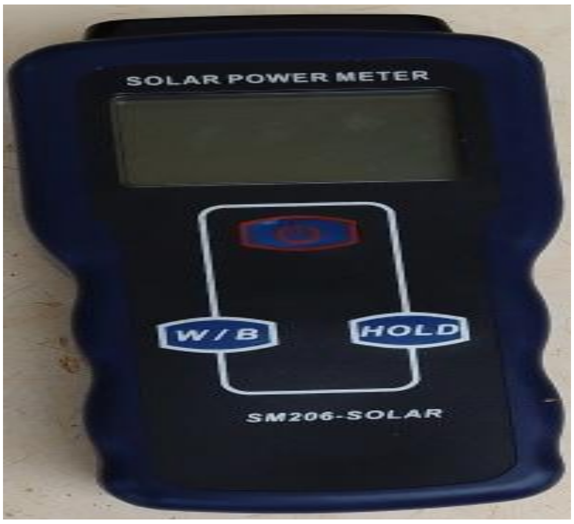
Material for Reflective Surface
A 3 mm thick glass mirror was used and selected because its reflectivity of 95% over the polished aluminum surface which is better than that of aluminum (85%).

Material for The Absorber/Pot
Aluminum was chosen as the material for the absorber (cooking pot) due to its low price, availability and specific heat per cubic centimeter. The choice is also due to its properties of corrosion resistance, high strength and low density. The aluminum is also non-toxic and was painted black for better absorbency, making it ideal for heating and melting paraffin wax.

Melting Materials and Heat Transfer Fluids
Paraffin wax was chosen as the dissolving material and mineral oil as the solvent added during melting because it is used in the cosmetics industry as an effective material for skin care. Water was also selected for its stability at high temperatures, low maintenance and material transportation costs, and safe use as a heat transfer fluid, water is the most commonly used fluid for heating homes.

Pyranometer

The Pyranometer is a device that converts received global solar radiation into a measurable electrical signal and is often used in climatological research or to monitor the operation of weather stations. The working principle of a pyranometer mainly depends on the temperature measurement difference between two surfaces, such as dark and transparent.



Thermocouple

A thermocouple is a thermoelectric device used to accurately measure temperature. It consists of a wire with two strands made of different metals connected at one end. Heating the junction creates an electrical current that is converted into a temperature reading using a thermocouple monitor.

Digital Weighing Scale

The digital scale is a highly sensitive laboratory device that can accurately measure weights in the sub-milligram range with high precision. It has a weighing range of $100g - 500g$ and a reading accuracy of $0 \cdot 1mg - 0 \cdot 001mg$

Methodology

Experimental Set Up

The parabolic solar cooker for the experiment was set up behind physics lab B at Kwara State Polytechnic. After the parabolic solar cooker has been setup and the ring and arm been fixed, the sun's radiation direction was gotten by a compass and the dish was facing the east. The pot was fixed on the pot hanger and it was adjusted until there was a convergence of solar radiation under the pot. A metallic arm was used as support structure for the reflector and the receiver. The system was adjusted to align with the direction of the sun. Water was poured into the pot and the pot was covered. After the water has reached a considerable temperature of $47 \cdot 6°C$, the smaller pot containing the wax was placed inside the bigger pot. This was done in order to maintain a mild temperature suitable to melt the paraffin wax efficiently, as excessive amount of heat could burn the wax. $133ml$ of mineral oil was added to the wax then the pot was covered. The ambient temperature, temperature of the pot bottom, side of the pot, air gap temperature of the pot and fluid temperature was taken at every $10mins$ interval until the wax was melted. The molten wax was poured into a container and allowed to cool. Perfume was also added to give the product a sweet smell.

Determination of Focal Length

According to Dasin et al 2011, to determine the focal length of a parabolic dish,

Focal distance, $F = \frac{r^2}{4h}$

Diameter of dish is 1.8m and height is 2.6m

Where

$$r = \frac{d}{2} = \frac{1.8}{2} = 0.9 \qquad h = 2 \cdot 6$$

$$F = \frac{0.9^2}{4 \times 2.6}$$

$$F = 0 \cdot 078m$$

Determination of The Parabolic Aperture Area

According to Mahendra et al 2020, the parabolic aperture area A is given as,

$$A = \frac{\pi D^2}{4}$$

$$A = \frac{3.142 \times 1.8^2}{4}$$

$$A = 2.5m^2$$

Determination of The Rim Angle

According to Craig (2015), the rim angle can be calculated as,

$$tan\theta = \frac{1}{\frac{D}{8h} - \frac{2h}{D}}$$

$$tan\theta = \frac{1}{\frac{1.8}{8 \times 2.6} - \frac{2 \times 26}{1.8}}$$

$$\theta = 20°$$

Determination of Cooking Power Estimation

The cooking power, P, is defined as the rate of useful energy available during heating period. It is measured in watt. According to Samuel *et al* 2021 it can be calculated as,

$$P = \frac{M_W C_W \ (T_f - T_i)}{t}$$

where P is interval cooking power (W), T_i is initial water temperature is final water temperature is mass of water (kg), and C_w is specific heat capacity (4186 J/kg K). $(4186\, J/kg\, K)$

$$P = \frac{2.5 \times 4186 \times (71.2 - 58.3)}{600}$$

$$P = 225W$$

The Quantity of Heat Power Q

According to Gundre et al 2012, The heating-power of a solar cooker is calculated as;

$$Q_{heat} = m_w C_w \frac{dT_a}{dt}$$

$$Q_{heat} = 2.5 \times 4186 \times \frac{4.8}{600}$$

$$Q_{heat} = 83.72W$$

Calculation of Efficiency

Based on first law of thermodynamic

$Input = Energy\ Output + Energy\ Loosses$

Energy input to the parabolic solar cooker can be calculated as follows:

$$E_i = I_b + A_{sc}$$

Where;

E_i = Energy Output

I_b = Solar Radiation

A_{sc} = Surface area of the solar cooker in m²

But

$$A_{sc} = \frac{\pi\left(\left(a^2 D^2 + 1\right)\right)}{6a^2}$$

Where $a = \frac{1}{4f}$

$$f = 7 \cdot 8cm = 0 \cdot 078m$$

$$a = \frac{1}{4 \times 0 \cdot 078}$$

$$a = 3.2m$$

Substitute a and other parameters into the equation, A_{sc} becomes;

$$A_{sc} = \frac{3 \cdot 142\left(\left(3 \cdot 2^2 \times 1 \cdot 8^2 + 1\right)\right)}{6 \times 3 \cdot 2^2}$$

$$A_{sc} = 1 \cdot 75m^2$$

Therefore,

$$E_i = I_b + A_{sc}$$

$$E_i = 1001 + 1 \cdot 75m^2$$

$$E_i = 1002 \cdot 75W$$

Where,

$$Efficiency\ (\eta) = \frac{Energy\ Output}{Energy\ Input} = \frac{E_o}{E_I}$$

$$E_o = (m_w C_w (T_{wb} - T_{wa})/t)$$

$$E_o = \frac{2.5 \times 4186(71.2 - 58.3)}{600}$$

$$E_o = 225W$$

$$\boldsymbol{Efficience}\ (\eta) = \frac{\boldsymbol{E_o}}{\boldsymbol{E_I}} = \frac{(m_w C_w (T_{wb} - T_{wa})/t)}{I_b + A_{sc}} \times 100$$

$$\eta = \frac{225}{1002 \cdot 75} \times 100$$

$$\eta = 22.44\%$$

Results and Discussion

Result

Some melting test were carried out on the parabolic cooker. Parameters measured include: solar radiation, ambient temperature, absorber temperature, side temperature, cover temperature, air gap temperature and water temperature at 10-minute intervals to melt the wax. At the end of the experiment, the collected data was analyzed and the data obtained from this experiment is shown in the graphs below:

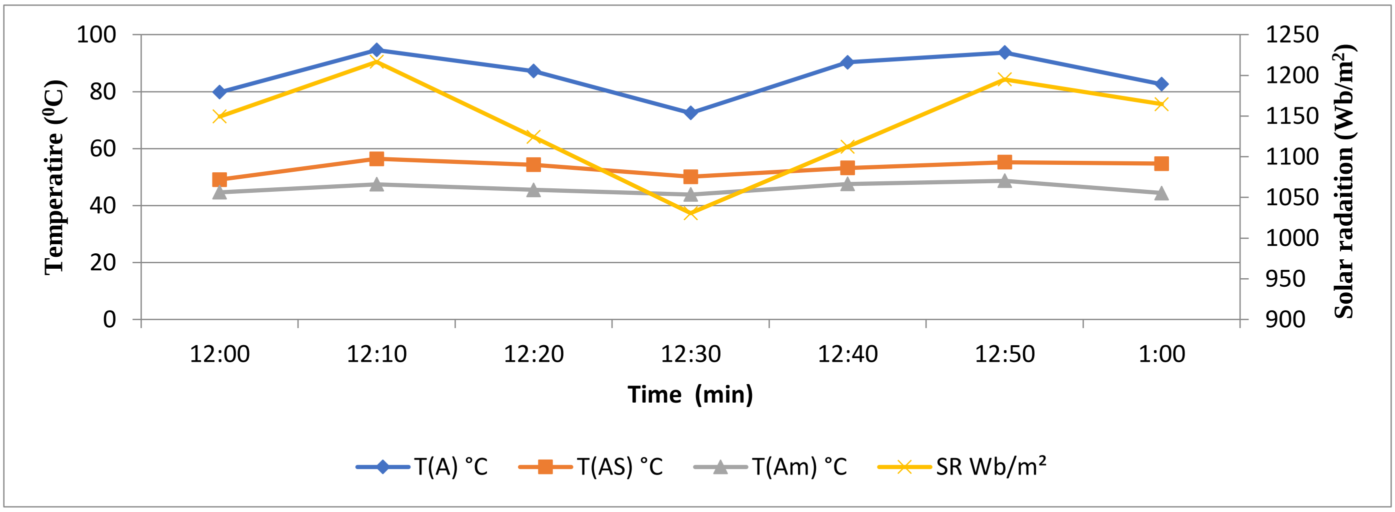


Fig 1. Showing the variation of the solar radiation and the temperature against time

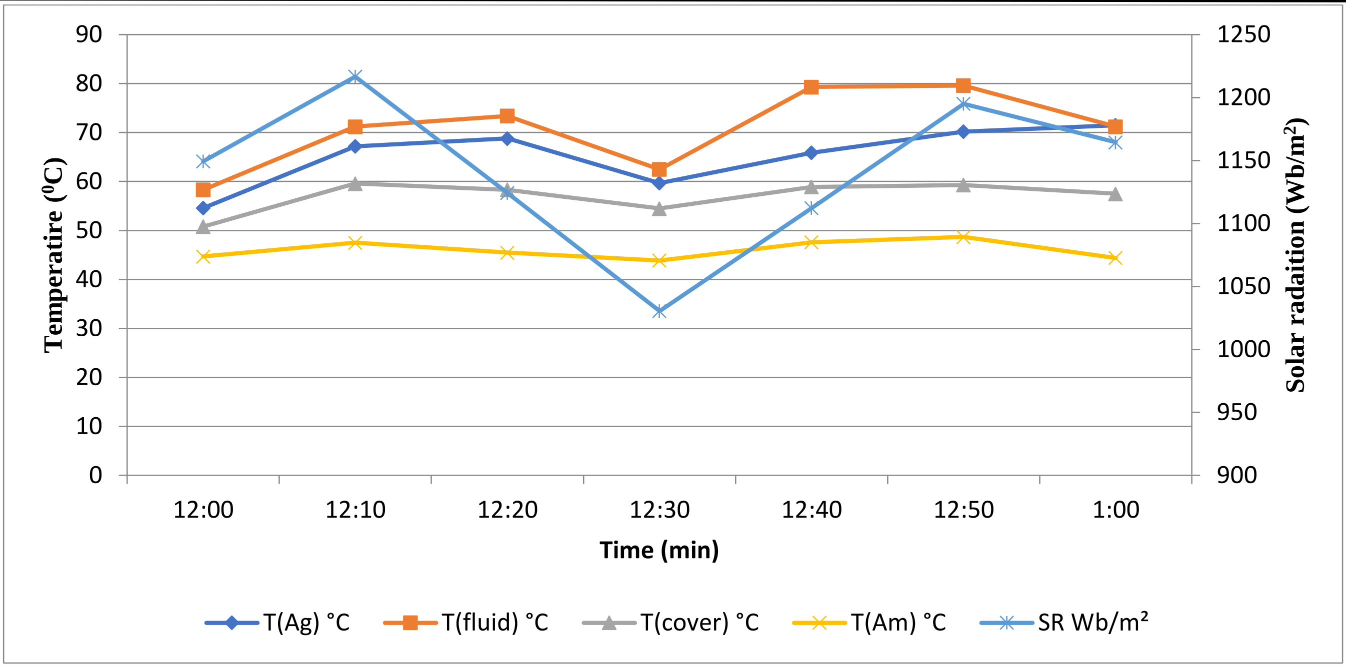


Fig 2. Showing the variation of the solar radiation and the temperature against time

Time (pm)	T(Ag) °C	T(A) °C	T(AS) °C	T(cover) °C	T(fluid) °C	T(Am) °C	SR Wb/m²
12:00	54.6	79.8	49.1	50.8	58.3	44.7	1149.4
12:10	67.2	94.6	56.4	59.6	71.2	47.5	1216.7
12:20	68.8	87.2	54.3	58.3	73.4	45.5	1124.3
12:30	59.7	72.5	50.1	54.5	62.5	43.9	1030.6
12:40	65.9	90.3	53.2	58.9	79.3	47.6	1112.3
12:50	70.2	93.7	55.2	59.3	79.6	48.7	1195.1
1:00	71.5	82.6	54.7	57.5	71.2	44.4	1164.5

Discussion

The experiment was conducted at Kwara State Polytechnic, Ilorin on May 12, 2023 between 12pm and 1pm.

Figure1 shows the variation of solar radiation and temperature as a function of time. From the graph we can see that as solar radiation increases, the ambient temperature also increases, this factor also influences other measured parameters. At the start of the experiment, the measured solar irradiance was $1114 \cdot 9\, W/m^2$, while the initial ambient temperature was $32℃$ and increased to $36℃$ after 10 minutes. The solar radiation measured after 10 minutes was $1216 \cdot 7\, W/m^2$, when the cooking fluid time increased from 12:00 to 12:10. The lowest ambient temperature measured during the experiment was $39℃$ and the lowest solar radiation measured during the experiment was $1030 \cdot 6\, W/m^2$. This result is similar to that presented by Adedeji *et al.* (2020) and Reddy *et al.* (2015) except that their initial ambient starting temperature were $28℃$ *and* $30℃$ respectively, while the initial insolation was $768\, W/m^2$ *and* $821\, W/m^2$.

Figure 2 shows the variation of solar radiation and temperature as a function of time. It can be clearly seen that the increase in solar radiation affects the temperature of the absorber (pot), which also affects the temperature of the other measured parameters and makes them increase. The highest solar radiation achieved was $1216 \cdot 7\, W/m^2$, the highest absorber temperature achieved was 93.7 and the highest fluid temperature achieved was $79 \cdot 6℃$, which is hot enough to melt paraffin. In the study of Claude *et al.* (2012) the variation in solar radiation which caused considerable increase in the temperature of the cooking material (pot) made the melting of the paraffin wax the used faster which is similar to the result obtained in this study.

With increasing solar radiation, the temperature of the fluid also increases, with decreasing solar radiation, the temperature of the fluid and the temperature of the absorber decrease, the ambient temperature, the temperature of the absorber side, the absorber cover increase the temperature and the air gap temperature each increase. The higher the ambient temperature due to increased sunlight, the faster the paraffin melts; and as the temperature decreases, the melting rate of the paraffin wax also decreases. The result presented by Tibebu and Hailu (2021) and Singh *et al.* (2020) was slightly different, they got a maximum of $60℃$, the thermal stability of their data was not achieved, it was affected because of the variation in wind speed and excessive cloud cover during their test days.

The total time taken for the entire experiment was 60 minutes. The Rim Angle was calculated to be $20℃$. The cooking Power of the parabolic Solar Cooker is $225W$. The quantity of heat obtained during the experiment is $83 \cdot 72W$. The efficiency of the parabolic solar cooker is 22.44%. Jacob *et al.* (2021) and Sawarn *et al.* (2021) based on their results which is similar to this study stated that the inclusion of more expensive materials in the construction of the parabolic solar cooker is required to achieve an increase in the efficiency and performance of the parabolic solar cooker whenever the ambient temperature is low due to cloudy weather conditions.

Ahmed *et al.* (2015) and Raza *et al.* (2021) in the result of their study which is similar to this work also presented that a higher efficiency can be achieved by modifying the thermal conductivity of the paraffin wax and the incorporation of a solar tracking system.

The Solar radiation (SR) falling on the exposed surface of the parabolic solar cooker used during the experiment is in the range of $1030 \cdot 6\,W/m^2$ to $1216 \cdot 7\,W/m^2$. Due to the solar radiation dropping over the surface of the parabolic solar cooker at the time of the experiment, the ambient temperature ranged from $44 \cdot 4℃\ to\ 48 \cdot 7$. The fluid temperature ranged from $58 \cdot 3℃\ to\ 79 \cdot 6℃$, the pot cover temperature ranged from $50 \cdot 8℃\ to\ 59 \cdot 6℃$, the pot side temperature ranged from $49 \cdot 1℃\ to\ 56 \cdot 4℃$, the Air gap temperature ranged from $54 \cdot 6℃\ to\ 71 \cdot 5℃$ and the pot (absorber) ranged from $72 \cdot 5℃\ to\ 94 \cdot 6℃$. The maximum Solar radiation was incident on the parabolic Solar cooker at $12{:}10pm$ Which is $1217 \cdot 6\,W/m^2$ and minimum Solar radiation was incident on the parabolic Solar cooker at $12{:}30pm$ which is $1030 \cdot 6\,W/m^2$. The ambient air that falls on the parabolic Solar cooker is heated up by the radiation of the Sun which is then drawn by the pot absorber and this heats up to $94 \cdot 6℃$ for $1216 \cdot 7\,W/m^2$ Solar radiation.

Conclusion

Parabolic solar cooking is a sustainable and environmentally friendly alternative to conventional heating and melting methods. Solar energy technology has made great technological and financial advances, but more research and development need to be done to make it efficient and acceptable compared to fossil fuels. The increasing global demand for this technology as well as the development of advanced components and systems can reduce costs. Technological advances and the use of low-cost parabolic solar cooking systems will allow future designs to operate for more hours in the day and some in the evening. In the near future, solar energy will play a significant role in the energy sector. Therefore, it is important to use solar energy proactively. Energy consumption in cooking accounts for a large proportion of total energy consumption in developing countries such as Nigeria. The parabolic solar cooker is a possible complementary cooking method to traditional methods. By design, the parabolic Solar cooker was made from materials available in the local market. After construction, the device was tested under various operating conditions and it was found that the parabolic Solar cooker could melt 171 g of wax in less than one hour, with the Solar radiation being 1164.5 W/m². Therefore, according to the result, the performance of the parabolic solar cooker is satisfactory. Although the construction and operating costs are low, this parabolic solar cooker can be promoted in remote and rural areas.

Recommendation

Based on the evaluation of the experiment conducted and the performance achieved, the parabolic solar heating method is strongly recommended for chemical, pharmaceutical, agricultural industries and scientific laboratories as a highly efficient alternative to traditional heating and cooling mechanisms. It is also recommended for science and engineering students in Nigeria. In addition, we recommend parabolic solar cooker users to use dark safety glasses during the heating and melting process.

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