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ORIGINAL ARTICLE

Design, manufacturing and performance evaluation of parabolic dish solar cooker using pentagonal shaped cooking vessel

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ABSTRACT

Improving access to clean and sustainable energy is crucial for enhancing social and economic development as well as quality of life. This study aimed to design, fabricate, and comprehensively evaluate the thermal performance of a parabolic dish solar cooker using a novel pentagonal-shaped cooking vessel.

The device's remarkable performance was assessed through rigorous no-load and load testing. The no-load tests revealed a maximum temperature of 280.52°C, with a notably high first Figure of Merit of 0.314 W/m². The load test results were even more impressive, demonstrating a second Figure of Merit of 0.539, a thermal efficiency of 42.04%, a cooking power of 480.68 W, and a standard cooking power of 0.539 W. Notably, the cooling test showed an optical efficiency of 0.37 and a low heat loss factor of 43.66 W/K.m². Furthermore, the solar cooker's capabilities were showcased by successfully cooking various food items, including rice, maize, and Shiro Wot, in a timely manner. These findings suggest the exceptional potential of parabolic dish solar cookers for cooking in isolated and off-grid areas, and emphasize the importance of addressing energy poverty and promoting environmental sustainability through the development of economical and eco-friendly cooking technologies.

***Keyword**: Renewable energy, solar energy, parabolic dish, pentagonal shaped cooker.*

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1. Introduction

Energy consumption in developed countries is growing at a rate of approximately 1% per year, and at a rate of 5% per year in developing countries [2]. This demand is increasing due to population growth and industrialization [1]. The energy demand is increasing every day, and petroleum-based fuels are not promoted to compensates for that growing demand, mainly because of decreasing world petroleum production and environmental pollution such as greenhouse effect and global warming [3]. Due to the increasing price of petroleum products, renewable energy has focused remarkable attention at the international level for the past two decades. Renewable energies have gained more and more interest in recent years for numerous reasons [4] such as the increase in fossil fuels' prices, the high concentration of CO_2 emissions, the need to reduce greenhouse gas emissions and the growing worldwide energy consumption [5], [6]. Renewable sources play a vital role in sustainable development and environmentally friendly energy sources [7], [8]. Solar energy is a promising alternative to conventional energy due to its greater global potential [6]. The greatest advantage of solar energy is the minimal usage of traditional and polluting source of energy. Hence the usage of solar energy leads to clean and hygienic environment and huge fuel savings [9].

Humans need to cook in order to survive [10], and in many nations, cooking accounts for a significant portion of energy use. Cooking accounts for a significant portion of home energy consumption in developing nations in Africa, Asia, and South America. According to a study by [11], around 80% of the countries in Sub-Saharan Africa still cook their food using firewood [12], fossil fuels, biomass, and electricity, which causes massive emissions of greenhouse gases and deforestation. This suggests that there is a need for more eco-friendly cooking techniques that make use of clean energy sources. Solar energy is regarded as an abundant and practical alternative to all other unconventional energy sources for thermal energy applications, specially for cooking [13], [14]. A solar cooker is a device that is used for cooking food using solar energy [15], [16] Solar cookers also allow some important processes like pasteurization and sterilization [17]. A solar cooker is a solar collecting device that uses the energy from the sun to cook food [18].

Concentrating solar collectors are the most developed technology for the use of solar energy owing to their higher temperatures in the focal zone [6]. The most well-known technologies for concentrating solar collectors are solar power towers, solar parabolic dishes, parabolic trough collectors and linear Fresnel reflectors [5]. Direct (concentrating) solar cookers are solar cookers that use one or more reflectors to focus and concentrate sunlight from the sun to the focal region where cooking takes place [6], [19]. These solar cookers consist of a framework that supports the reflectors and a pot utilized for cooking. The arrangement of this type of cooker is in such a way that it allows the reflectors to be tilted to always point towards the sun, with the cooking pot always in the focal region. The power output of these cookers depends on the area of the design, the intensity of the solar radiation, the reflectivity of the material and the geometry. These types of cookers achieve the highest cooking temperatures for faster cooking speeds and are relatively inexpensive. There are essentially four types of concentrating solar cookers, which are parabolic, cylindrical, spherical, and Fresnel cookers.

A parabolic solar cooker is a concave shaped dish whose inner surface is made of reflective material that concentrates solar radiation onto an absorbing device, which is usually a darkened cooking pot [10], [20]. The design of a parabolic dish relies on many parameters that require research in many areas such as, the reflector material of the concentrator, the diameter of the parabolic dish concentrator, sizing the aperture area of the concentrator, focal length of the parabolic dish, the focal point diameter, sizing the aperture area of the receiver, geometric or area concentration ratio, and rim angle. The parabolic dish concentrator works by concentrating the sunlight to the focus of the parabolic reflector and placing the receiver at the focal point. The receiver accumulates the heat, which is then transported to the end use application with the help of a heat transfer fluid [6]. The surface area of the receiver is much smaller than that of the dish reflector, thereby higher concentration ratio can be achieved. This concentration allows the increase of energy flux and attainment of higher temperatures at the receiver [9].

A number of tests were conducted under varying operating conditions to determine the stagnation temperature, load Temperature and to study the heat capacity of the cooker. The experimental results have been analyzed and discussed in detail in the discussion section. Although solar cookers are not a recent novel idea, they have undergone several modifications over the years. However, there is still room for improvements in order to achieve higher efficiency, lower cost, greater portability, and further adaptability to different environmental conditions.

Most parabolic dish solar cookers utilize a standard circular or cylindrical cooking vessel. In contrast, this research employed a unique pentagonal shape for the cooking vessel in the parabolic dish solar cooker design. The use of this distinctive pentagonal shape represents the key novel aspect of the work. By evaluating the thermal performance and cooking capabilities of the parabolic dish solar cooker with this pentagonal-shaped vessel, the researchers seek to investigate whether the alternative geometry can provide any advantages or improvements over the conventional circular/cylindrical vessel designs. The existing literature on parabolic dish solar cookers reveals that most prior studies have focused on employing standard circular or cylindrical cooking vessels in the design. While these conventional vessel shapes have been widely investigated, there is a lack of research exploring alternative geometries that could potentially enhance the thermal performance and overall efficiency of parabolic dish solar cookers. This study seeks to address this gap by incorporating a novel pentagonal-shaped cooking vessel into the parabolic dish solar cooker design. The unique pentagonal shape has not been extensively explored in prior parabolic dish solar cooker research, presenting an opportunity to investigate if this alternative geometry can offer any advantages over the more commonly used circular or cylindrical vessels. The primary objective of this work is to conduct a comprehensive evaluation of the thermal performance and cooking capabilities of the parabolic dish solar cooker with the pentagonal-shaped cooking vessel. This includes assessing parameters such as thermal efficiency, cooking power, and overall system effectiveness under various operating conditions. The novelty of this research lies in the novel application of a pentagonal-shaped cooking vessel, which represents a departure from the typical circular or cylindrical geometries used in prior parabolic dish solar cooker studies. Investigating the performance implications of this unique vessel shape is highly relevant, as it could lead to enhanced thermal efficiency, improved cooking capabilities, and ultimately, more effective solar cooking systems that can better meet the needs of communities lacking access to reliable energy sources.

2. Materials and methods

2.1 Reflecting material

Reflective materials are materials that reflect light back to its source. They have a wide range of applications, including solar concentration. The most commonly used materials for this application include glass mirror, aluminum foil, stainless steel sheet and silver foil as shown in Table 1.

Table 1. List of materials for reflecting surface [13].

Material	Reflectivity	Cost
Glass mirror	96	Relatively high
Aluminum foil	85	Relatively law
Stainless Steel sheet	60	Relatively high
Silver Foil	95	High

2.2 Design of solar parabolic concentrator

In a parabola, all the incoming solar rays from a light source are reflected back to the focal point of the parabola. The solar concentrator was developed using a semi-spherical surface covered with many small sections of mirrors to form a segmented, spherical concentrator. The frame of the parabola was made from a mini dish satellite receiver plate. The solar concentrator takes advantage of all incoming solar radiation and concentrates it at the focus.

Fig. 1 shows the parabolic dish concentrator parameters. The equation for the parabola in cylindrical coordinates is given by:

$$Z=\frac{r^2}{4f} \tag{1}$$

The diameter of the opening parabolic surface is d, and the focal distance of the parabola is f. the surface of this parabola is given by:

$$S=\{[1+(\frac{d}{4f})]^{\frac{3}{2}}-1\} \tag{2}$$

The cross-section of the opening is:

$$A=\frac{\pi d^2}{4} \tag{3}$$

To calculate the focal distance, the following equation is use

$$f=\frac{d^2}{16h} \tag{4}$$

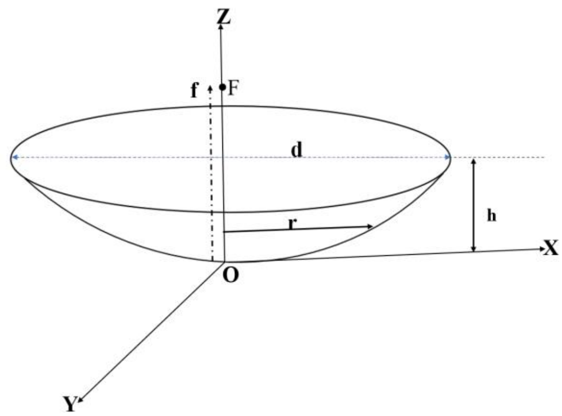


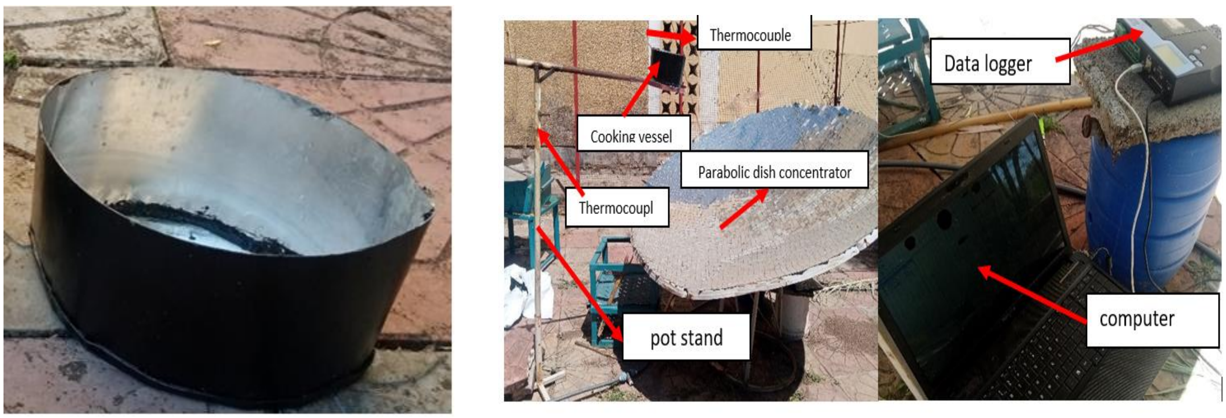
Fig. 1. Parabolic dish concentrator parameter.

For this research work, glass mirror is used as a reflecting material due to its high reflective index closed to 96% reflectivity index.

Table 2. Technical description of parabolic dish concentrator

Aperture diameter	1.31m
Surface area	1.34 m^2
Focal length	0.89 m
Height	0.121 m
Parabolic radius	1.04 m
Rim angle	45°

Fig. 2. Parabolic dish with mirror glass reflector.



(a) (b)

Fig. 3. a) black painted pentagonal shaped aluminum cooking pot b) experimental setup.

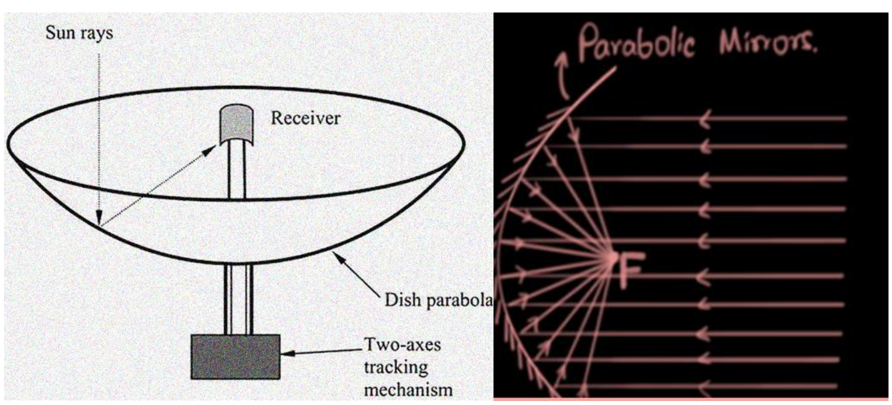


Fig. 4. Schematic of a parabolic dish collector.

2.2 Tools and instruments

Different tools and instruments are used for the measurement of different properties. the major tools and instruments used are.

Table 3. Tools and instruments

No.	Instrument type	Description
1	K-type thermocouple	Used to measure the temperature inside the cooking pot and the ambient temperature.
2	Data logger	Used for data acquisition system by connecting it with thermocouples and computer. In this research work, a 2020 series data logger is used.
3	Lux meter	Used to measure the illuminance at a specific surface.
4	Wind meter	Used to measure wind speed as it has a great impact on solar cooker performance.

3. Result and discussion

The experimental tests were carried out in the city of Bahir Dar with a latitude of 11°36′ N, a longitude of 37°23′ E, and an elevation of roughly 1,799 meters above sea level. It is located about 578 kilometers to the north-northwest of Addis Ababa.

3.1 Experimental testing

Two types of experimental tests were carried out, a stagnation test (idle test) and a load test. Tests without a load made it possible to evaluate the maximum achievable temperature of the solar cooker. Experiments with loading were carried out by filling a 4.5-liter amount of water into the cooker, which is made of aluminum cooking vessels.

3.1.1 Stagnation test

The stagnation test provides information on the maximum temperature the cooking vessel can reach at a specific solar insolation level. Mathematically, it is expressed as:

$$F_1 = \frac{T_{max} - T_a}{I_b} \tag{5}$$

The minimum area of the cooking vessel bottom required to absorb 1 joule of heat energy radiated to the pot from the solar cooker per second due to the temperature difference is revealed by the slope of the curve F_1 against the temperature difference. The empty pot was put on the pot stand with the sun's rays concentrated at the pot bottom for this initial Figure of Merit test, which was carried out under a no-load scenario.

The test was run between 10:00 AM and 14:00 PM. Fig. 5-10 depicts the outcome of the stagnation temperature for both cooking vessels. The stagnation test on the pentagonal shaped cooking vessel carried out between 10:00 AM and 11:00 AM. On the test day, the ambient temperature was 27.2, 27.55, and 27.83°C on average on each day respectively.

In contrast, the maximum simulated temperature of 305.65°C was recorded at 12:36 PM, indicating that it took four minutes less time to reach the maximum temperature. Additionally, on the same day, the maximum temperature of 280.09°C was measured at the bottom of the pentagonal shaped cooking vessel at 10:43 AM with a beam radiation of 803.91 W/m^2, while the maximum simulated temperature of 289.98°C occurred at 10:40 AM.

Similarly, at 10:41 AM on the same day, the pentagonal shaped cooking vessel reached a maximum temperature of 279.48°C at the bottom, with a beam radiation of 793.74 W/m^2. The maximum simulated temperature occurred at 10:40 AM, measuring 288.73°C.

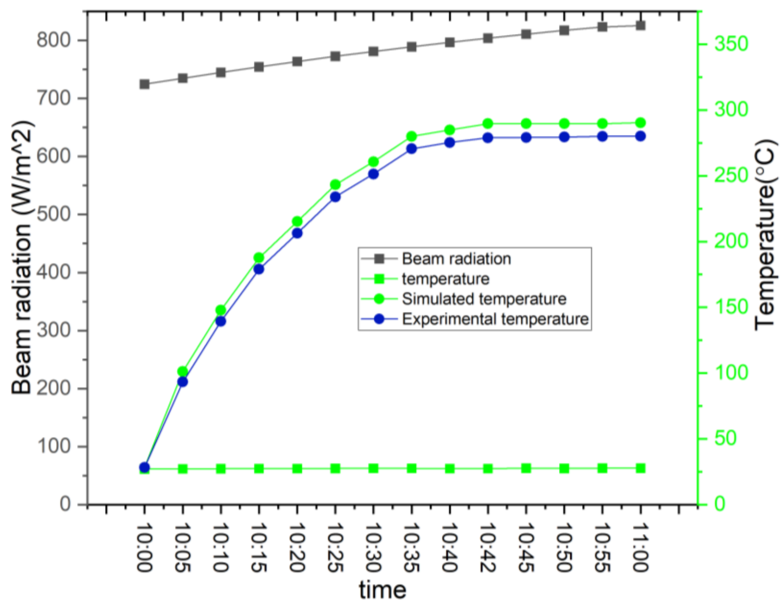


Fig. 5. Stagnation temperature test on pentagonal shaped cooking vessel on test-1.

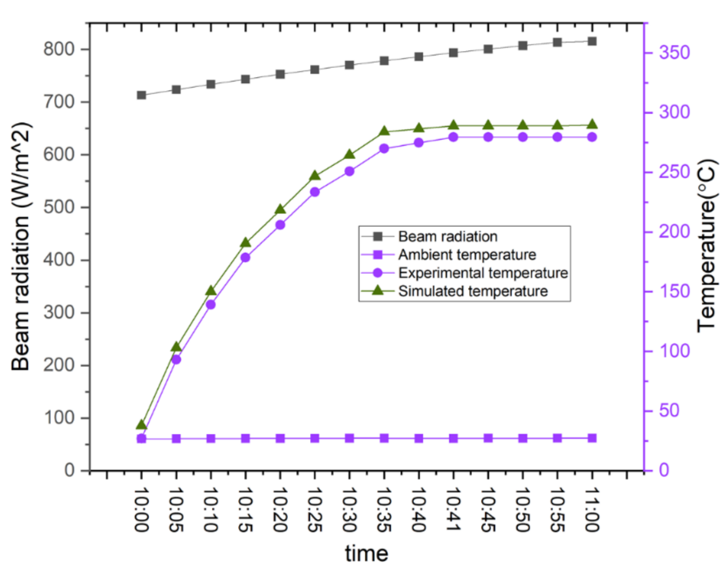


Fig. 6. Stagnation temperature test on pentagonal shaped cooking vessel on test-2.

Similarly, the pentagonal shaped cooking vessel recorded a maximum temperature of 282°C at the bottom, with a beam radiation of 802.05 W/m^2, at 10:42 AM. The maximum simulated temperature of 294.88 °C occurred at 10:38 AM.

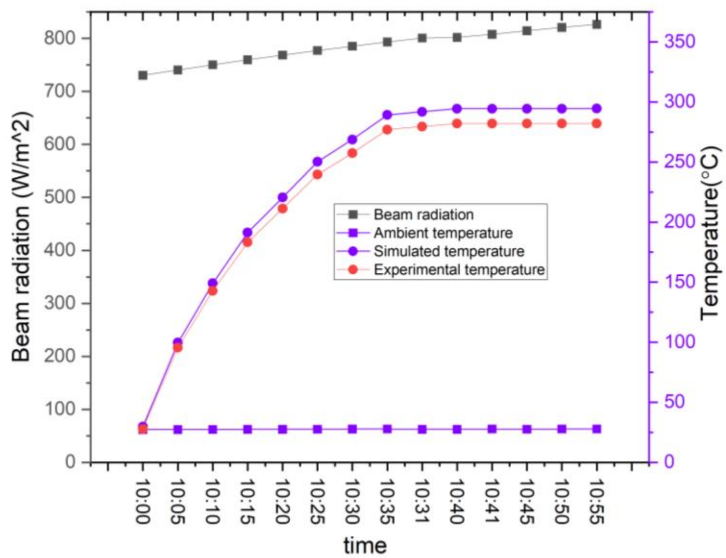


Fig. 7. Stagnation temperature test on pentagonal shaped cooking vessel on test-3.

3.1.2 First Figure of Merit (F_1) of pentagonal shaped cooking vessel

The stagnation test on the pentagonal-shaped cooking vessel is a technique to determine the quality of the cooker from the perspective of optical efficiency and thermal performance. As shown in equation (6), the first figure of merit (F_1) was calculated.

The following values were obtained from the experiment to calculate the first figure of merit. Ta = 27.18℃, T_{max}= 300.88℃, I_b = 855.89 W/m^2

$$F_1 = \frac{(T_{max} - T_a)}{I_b} \tag{6}$$

Equation (2) was used to calculate F_1. The obtained value of F_1 is 0.319 ℃. m^2/W. On test-1 F_1 was 0.319 and on test-2 it was 0.318. The experimental result for F_1 for three days shows that the values are relatively close together (ranging from 0.318 to 0.32), which could suggest that the experimental setup was consistent and reliable. According to the permissible standard F_1, the test states that if the value of F_1 is above 0.12, the cooker is marked as A-grade and if F_1 is below 0.12 the cooker is marked as a A-grade solar cooker [21]. The cooker constructed is marked as an A-grade solar cooker.

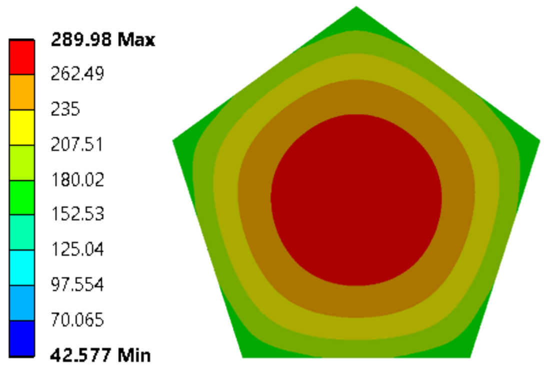


Fig. 8. Temperature distribution at the bottom of the pentagonal shaped cooking vessel test-1.

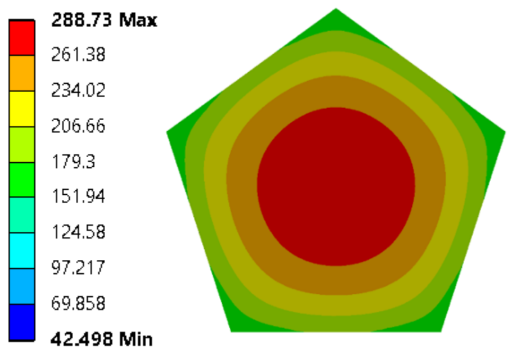


Fig. 9. Temperature distribution on the bottom of the pentagonal shaped cooking vessel test-2.

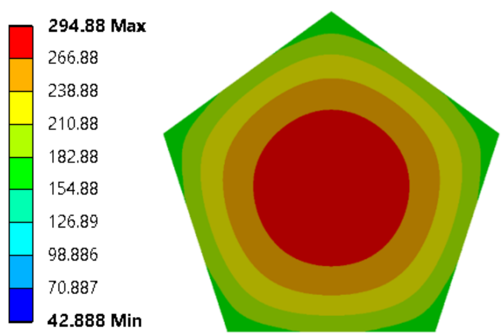


Fig. 1. Temperature distribution at the bottom of the pentagonal shaped cooking vessel test-3.

3.1.3 Water boiling Test for pentagonal shaped cooking vessel

This test was conducted in 2023 G.C. For pentagonal-shaped cooking vessels, the water temperature during the period of the test reached values between 60-94℃ respectively, at insolation values from 781 W/m^2 to 834.13 W/m^2 between the hour of 10:20 AM and 10:35 AM. The average solar radiation and ambient temperature observed during the period of the test were 802.36 W/m^2 and 28.5℃, respectively. Fig. 11, Fig. 12, and Fig. 13, show the temperature of water during the test on test-1, test-2 and test-3, respectively. After the water heating test, the water-cooling test was performed by shading the solar cooker in order to prevent it from solar radiation. Fig. 14, Fig. 15, and Fig. 16 shows the water cooling test for the pentagonal shaped cooking vessel on March 8, 9 and 11, respectively.

On March 8, the water load test on both cooking vessel was carried out. On pentagonal shaped cooking vessel the test starts at 10:00 AM and lasts at 10:40 AM. At 10:40 AM the water starts to boil after this the water-cooling test follows by shading the solar cooker in order to prevent the solar cooker from getting solar radiation. On this day the water took around 132 minutes to get back to its initial temperature. On March 9 the boiling time was 40 minutes and the cooling time was around 128 minutes. Whereas on March 9 the boiling time was 43 minutes and the cooling time was 129 minutes.

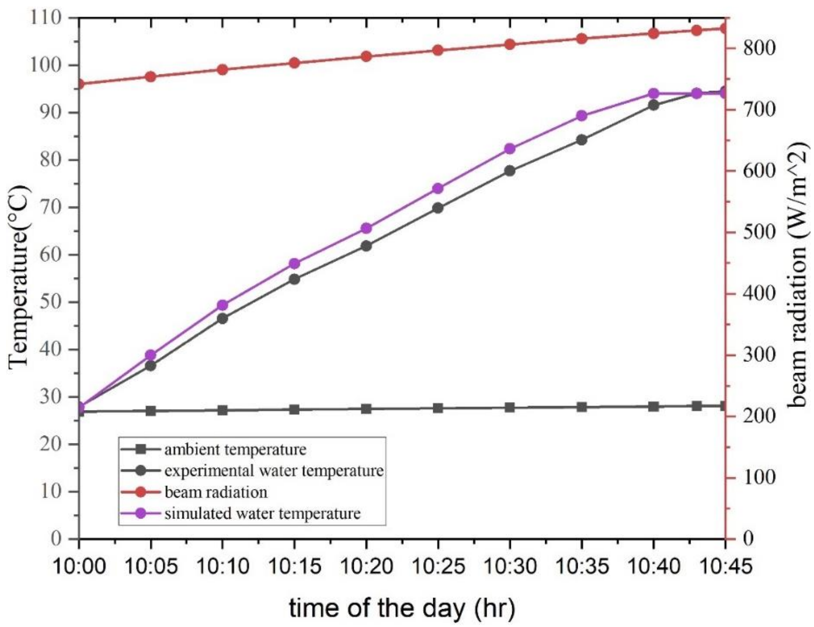


Fig. 2. Water heating test for pentagonal shaped cooking vessel on test-1.

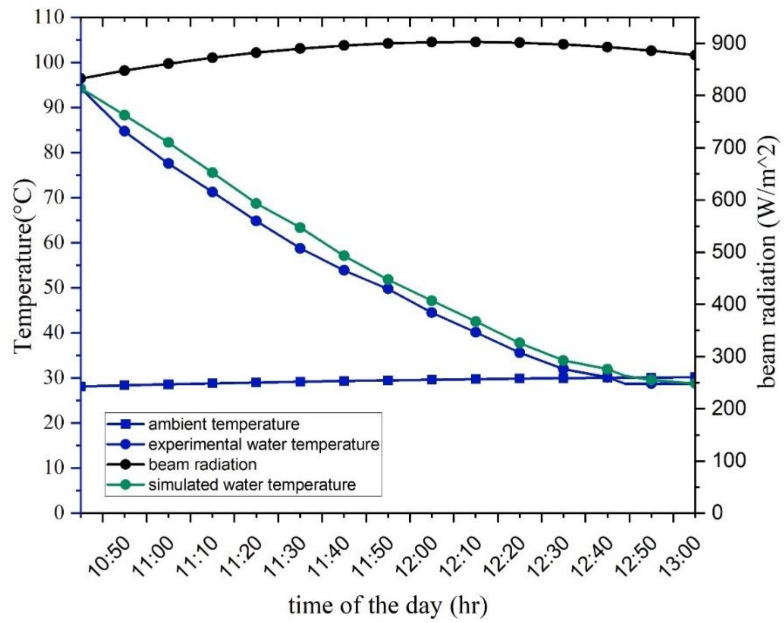


Fig. 3. Water cooling test for pentagonal shaped cooking vessel on test-1.

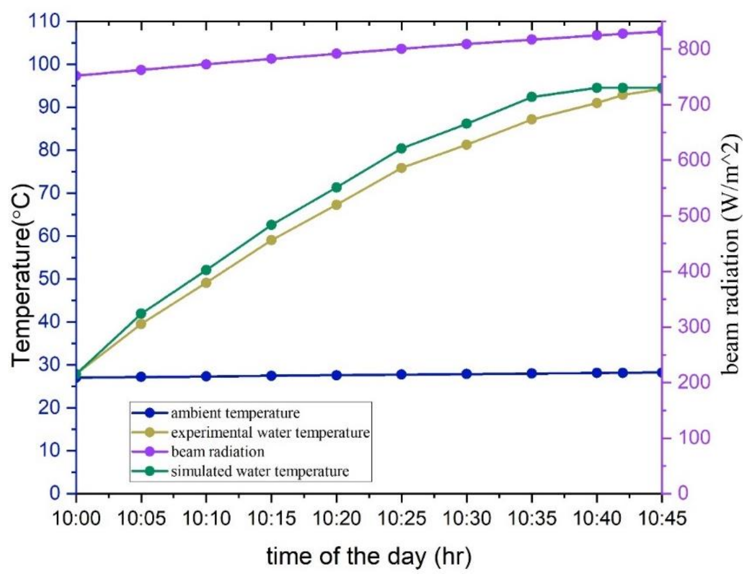


Fig. 4. Water heating test for pentagonal shaped cooking vessel on test-2.

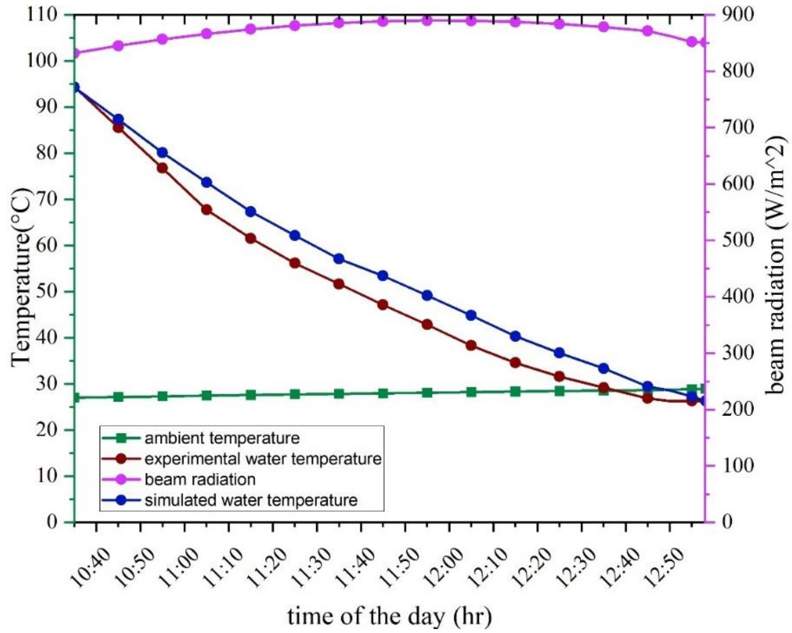


Fig. 5. Water cooling test for pentagonal shaped cooking vessel on test-2.

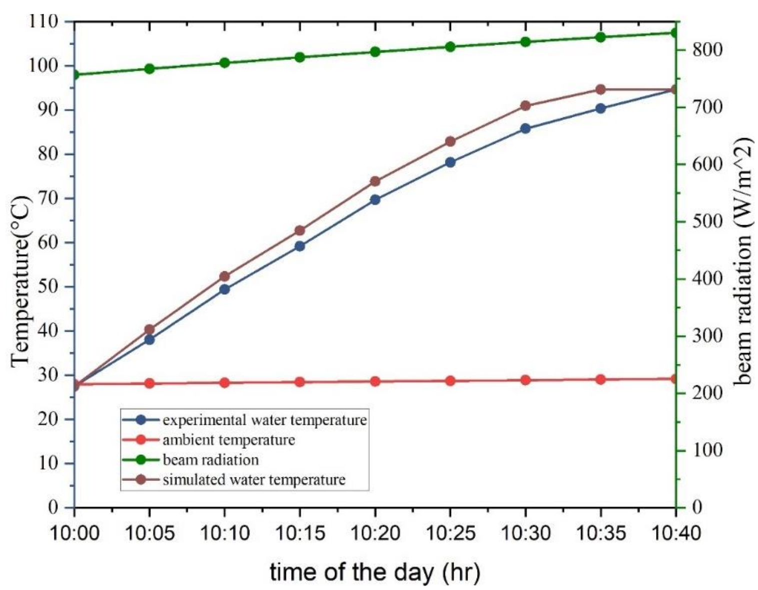


Fig. 6. Water heating test for pentagonal shaped cooking vessel on test-3.

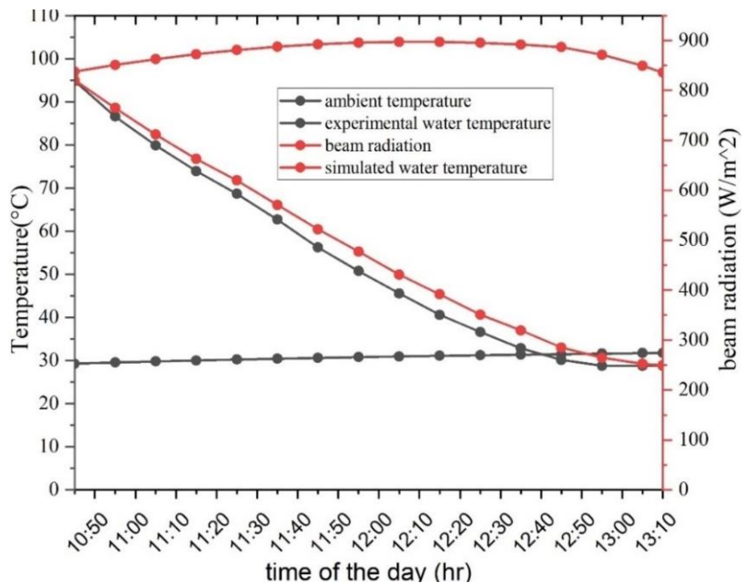


Fig. 7. Water cooling test for pentagonal shaped cooking vessel on test-3.

3.1.4 The second Figure of Merit (F_2) on pentagonal shaped prism cooking vessel

The second figure of merit (F_2) of both cooking vessels evaluated under full load conditions can be defined as the product of the heat exchanger efficiency factor (F') and the optical efficiency ($\eta_O = \alpha\tau$). F_2 takes into account the heat exchange efficiency of cookers and is obtained through the sensible heating of the water load as expressed by [22]. It can be 90 or 94^0C to avoid errors in reading the experimental curve, since the curve is at a higher temperature i.e., around the boiling temperature of the water.

The average ambient temperature and the average solar radiation intensity between the start and end time were calculated.

F_1 = 0.359 ℃. m^2/W, Mw = 4.5Kg, C_w = 4200 J/Kg. K, Ta = 28.59 ℃, T_{w1} = 28 ℃, ℃, T_{w2} =94 ℃ and I_b = 855.89 W/m^2, A = 1.34 m^2, t= 2040 s

$$F_2 = \frac{F_1(M_w * C_w)}{A_{ap} * \tau} ln\left[\frac{1-\frac{1}{F_1}\left(\frac{T_{w1}-T_a}{I_b}\right)}{1-\frac{1}{F_1}\left(\frac{T_{w2}-T_a}{I_b}\right)}\right] \tag{7}$$

The second Figure of Merit of pentagonal shaped cooking vessel on Test-1, Test-2 and Test-3 was 0.555, 0.537 and 0.524 respectively. To determine whether the experimental values are consistent, average and standard deviation of the F_2 values for the three days are calculated.

The average F_2 value is:

$(0.555 + 0.537 + 0.524)/3$ =0.5387

The standard deviation is:

$$\sigma = sqrt\left[\frac{(0.555-0.5387)^2+(0.537-0.5387)^2+(0.524\ -0.5387)^2}{3}\right]$$

$$\sigma\ =\ 0.01301$$

The criteria for the F_2 value according to the Indian standard are that F_2 should be greater than 0.42. the obtained solar second Figure of Merit on this study is greater than 0.42, therefore this solar cooker is first grade solar cooker.

3.2 Cooking power during test

On March 8, 9 and 11, 2023, a cooking performance experiment was carried out according to the international standard method. The test was carried out for a load of 4.5 kg of water.

$$P=\frac{M_w C_{pw}(T_{w2}-T_{w1})}{\Delta t} \tag{8}$$

The standardized cooking power is then obtained from the cooking power where each interval is corrected to standard insolation of 700 W/m^2

$$P_s = P\left(\frac{700}{I_b}\right) \tag{9}$$

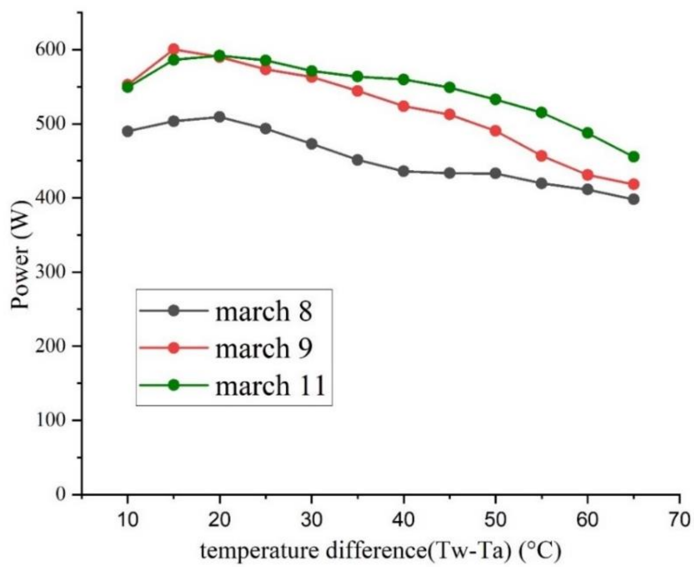


Fig. 8. Cooking power test on the pentagonal shaped cooking vessel.

The power output of a parabolic dish solar cooker using a pentagonal shaped cooking vessel on three different average tests for various temperature differences between the temperature of the water in the cooking vessel (Tw) and the ambient temperature (Ta).

As the temperature difference between the water in the cooking vessel and the ambient temperature increases, the power output of the solar cooker also increases. This is because a larger temperature difference results in a greater thermal gradient, which drives heat transfer from the solar collector to the cooking vessel. Overall, the power output of the solar cooker appears to be relatively consistent across the three days of the experiment, with some minor variations between different temperature differences. On test-2, the power output of the solar cooker is generally higher than on the other two days, which is be due to high beam radiation on that day.

When comparing the three days of the experiment, there are some differences in power output for different temperature differences, but the differences are not as pronounced as for the pentagonal shaped cooking vessel.

3.3 Efficiency of the solar cooker

Generally, the efficiency of a solar cooker is measured by its cooking power, which is the amount of energy that the cooker can deliver per unit of time. The cooking power of a solar cooker is determined by the amount of sunlight that it can capture and convert into heat, as well as the ability of the cooker to retain that heat and transfer it to the food being cooked.

One of the main factors that affects the efficiency of a solar cooker is its design. A well-designed solar cooker should be able to capture as much sunlight as possible and focus it on the cooking pot. This can be achieved through the use of reflectors, which can be made from a variety of materials, including aluminum foil, Mylar, or polished metal. The reflectors are positioned around the cooking pot to concentrate the sunlight it, which increases the temperature inside the cooking vessel.

The materials used to make the cooker can also affect its efficiency. For example, a cooker made from dark-colored materials will absorb more sunlight and heat up more quickly than a cooker made from light-colored materials. Additionally, the type of cooking pot used can affect the efficiency of the cooker. A black pot with a lid is typically the most efficient, as it absorbs more sunlight and retains heat better than a pot with a lighter color or without a lid [23].

The weather conditions can also impact the efficiency of a solar cooker. Cloudy or overcast skies will reduce the amount of sunlight available, which can make it difficult to achieve high cooking temperatures. Windy conditions can also reduce the efficiency of a solar cooker, as they can cause heat to escape from the cooking pot and make it more difficult to maintain a consistent temperature.

Efficiency of solar cookers can be calculated as:

$$\eta = \frac{Energy\ output}{Energy\ input} = \frac{E_o}{E_i} = \frac{M_W C_{PW}(T_{W2} - T_{W1})}{I_b A_p t} \tag{10}$$

The heat loss factor is a measure of how much heat is lost from a solar cooker during the cooking process. It is affected by a number of factors, including the insulation of the cooking pot, the ambient temperature, and the wind speed.

To improve the efficiency of a solar cooker, it is important to minimize the heat loss factor as much as possible. This can be achieved through a variety of measures, such as using a well-insulated cooking pot, positioning the cooker in a sheltered location to reduce wind exposure, and using reflectors to concentrate the sunlight onto the cooking pot. By reducing the heat loss factor, it is possible to increase the temperature inside the cooking pot and reduce the cooking time, leading to a more efficient use of solar energy.

3.4 The heat loss factor

The overall thermal efficiency of a solar cooker is typically expressed as the product of two factors: F' and U_l, F' represents the fraction of solar radiation that is absorbed by the cooker, and is a function of the color and material of the cooker's surface, as well as the angle of the sun,U_l represents the overall heat loss coefficient of the cooker, which takes into account the conductive, convective, and radiative heat losses from the cooker. This value depends on the design and materials of the cooker.

The overall thermal efficiency of a solar cooker can be calculated using the formula:

$$F'U_L = \frac{\left((M_w C_w) + (M_p C_p)\right)}{\tau_o A_t} \qquad (11)$$

where M_w is the mass of water that is heated by the cooker, C_w is the specific heat capacity of water, M_p is the mass of the cooking vessel, C_p is the specific heat capacity of the cooking vessel, τ_o is the time constant, and A_t is the surface area of the cooking vessel.

In general, a higher value of $F'U_l$ indicates a more efficient solar cooker, as it means that more of the solar energy is being used to heat the water and cook the food, and less is being lost to the environment.

3.5 Optical efficiency factor

The optical efficiency factor is a critical parameter for evaluating the performance of a solar cooker since it determines the amount of solar energy that is available for cooking. Solar cookers with higher optical efficiency factors will be able to generate more heat and cook food faster, which is particularly important in areas with limited sunlight or during cloudy or rainy weather conditions. Therefore, increasing the optical efficiency factor of a solar cooker is an important design goal for improving its performance.

$$F'\eta_o = \frac{F'U_l}{C} \frac{\left[\frac{(T_{W2} - T_a)}{I_b} - \frac{(T_{W1} - T_a)}{I_b} e^{-\frac{t}{t_o}}\right]}{1 - e^{-\frac{t}{t_o}}} \qquad (12)$$

For pentagonal shaped cooking vessel

$$\eta = \frac{4.23 * 4200(94 - 28.3)}{(830 * 1.34 * 40 * 60} = 0.431$$

On March 9 and 11 the efficiency of the cooking vessel is 0.434 and 0.396, respectively

$$F'U_l = \frac{(4.23 * 4200) + (0.378 * 900)}{2400} = 30.81$$

The heat loss factor for March 9 and 11 is 33.1 and 31.91 respectively

$$F'\eta_o = \frac{57.155}{8.03} \left[\frac{\frac{94 - 29.39}{883.41} - \left(\frac{26.92 - 29.39}{883.41}\right) e^{\frac{3480}{7920}}}{1 - e^{\frac{3480}{7920}}}\right] = 0.352$$

For March 9 and 11 optical efficiency factor found are 0.383 and 0.368, respectively.

3.6 Food cooking test

To conduct the food test on the solar cooker, a recipe consisting of rice, Shiro Wot, and Nefro was selected. The cooking vessels were preheated for at least 2-3 minutes before adding the food, and they were positioned in a location that received direct sunlight. The food was checked periodically to ensure even cooking and determine when it was fully cooked.

Table 4. Quantity and time interval of foods that are cooked by parabolic solar cooker.

Experiment day	**Cooked food**	**Cooking time interval pentagonal shaped cooking vessel**		**Quantity**
		Food item	Time	
test-1	Rice		12:00 to 12:40	Rice (300 g) + 0.5 L water
test-2	*S*hiro wet		12:00 to 12:19	Flour pea (9 soup spoons) + 1 L water
test-3	Maiz (Nefro)		12:00 to 12:40	Maize (300 g) + 0.5 L water

4. Conclusion

The purpose of this study was to design, build, and assess parabolic dish solar cookers' thermal performance. The cookers were designed with a steel plate and a reflector made of mirror glass to concentrate sunlight and produce high cooking temperatures. By preparing food and keeping an eye on the temperature at the bottom of the cooking pot, which represented the energy concentration, the device's efficacy was evaluated. The midway temperature reached 280.52°C, according to the no-load test findings; the initial figure of merit was 0.314°C/W/m^2. The results of the load testing indicated that the thermal efficiency, cooking power, standard cooking power, and second Figure of Merit were, in order, 480.68 W, 42.04%, 555.1 W, and 0.539 W. The results of the cooling test showed heat and an optical efficiency of 0.37, and heat loss factors of 43.66 W/K m^2.

The Energy Balance Equation $M_w C_w + M_p C_p$ = 17887.5 suggests the system has a substantial 17,887.5-unit thermal capacity, indicating its ability to effectively store and retain thermal energy, which is crucial for the efficient operation of the parabolic dish solar cooker. The time constants $\tau_o(s)$ = 3580.2 and τ(s) = 2460 reveal the system has relatively slow thermal response times. The longer time constant $\tau_o(s)$ likely represents the time for the system to reach 63.2% of its steady-state value, while the shorter τ may reflect the time to reach 63.2% of its maximum temperature change. These time constants are important for understanding the system's dynamic behavior and heat transfer characteristics.

The parameter $F'U_L$ = 43.66, representing the product of the collector efficiency factor F' and the overall heat transfer coefficient U_L, indicates the solar collector's overall heat transfer performance is moderate. Additionally, the parameter $F'\eta_o$ = 0.37 shows the combined optical and collector efficiency is around 37%, suggesting a significant portion of incident solar radiation is not effectively converted into useful thermal energy. The relatively low overall heat transfer coefficient U_L = 50.05 suggests room for improvement in heat transfer optimization. However, the high collector efficiency factor F' = 0.88 implies that the solar collector design effectively minimizes various heat loss mechanisms. The power output P(W) = 555.1 represents a moderate level of performance, which may be further improved through design optimization. The study also included cooking experiments using different amounts of food and water. While it took only 19 minutes to cook Shiro Wot in one liter of water, it took forty minutes to boil rice and maize in half a liter of water and 300 grams. Based on its findings, the study verifies the practicality of solar cookers with parabolic dishes for cooking. The study improves the subject of environmentally and economically sustainable cooking technology and emphasizes how important it is for global development efforts to solve energy poverty and environmental sustainability.

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