Development and Thermal Performance of a Parabolic dish solar cooker

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DOI: 10.29322/IJSRP.12.06.2022.p12619
http://dx.doi.org/10.29322/IJSRP.12.06.2022.p12619

Paper Received Date: 21st May 2022
Paper Acceptance Date: 6th June 2022
Paper Publication Date: 14th June 2022

Abstract- Solar energy is the renewable energy that can be used to provide, clean and cost- effect energy for cooking food by using a solar cooker. A parabolic solar cooker that uses glass reflective materials was developed. The developed solar cooker has a concentrating surface area of 2.5 m2, a focal length of 0.65m, and a depth of 0.4m. The thermal performance of the solar cooker was conducted in Central Regions in Tanzania. The cooking food substances tested were water, meat, and beans. The average maximum temperature attained was 121 ^{o}C. The time taken to boil water was 15mimutes whereas the time taken to cook meat and beans were 50 minutes and 90 minutes respectively.

Index Terms- Solar energy, Parabolic solar cooker, Thermal performance, Reflective material.

I. INTRODUCTION

The oil crisis and environmental pollution have been major challenges in the world today. Most developing countries use traditional biomass and fossil fuel for cooking food; however, these sources of energy have environmental and health impacts caused by deforestation and greenhouse emissions (Lentswe et al., 2021). Rising oil price and environmental pollution in the world have pushed for research and innovation of alternative source of energy which is affordable and clean for the environment. Solar energy is clean renewable energy, safe for food cooking, does not have environmental impacts and health risks (Battocchio et al., 2021). Tanzania is blessed with solar energy which could potentially be used for cooking. The average solar energy levels range from 2800h to 3500h of sunshine per year and solar radiation 4-7kWh/m2/day (Bishoge et al., 2018).

The solar cooker is a device that can change solar radiation into heat energy for cooking. There are many factors affecting the performance of the solar cooker, and one of them is the reflective materials. Ahmed et al., (2020) studied the performance of the parabolic solar cooker for rural households and refugee camps. Three types of reflective materials namely; Stainless Steel, Aluminum Foil, and Mylar tape were compared. The results showed that Mylar tape performed better as compared to Stainless Steel and Aluminum Foil. Ladan Mohammed, (2012) investigated the performance of parabolic solar cookers with different refractors namely; aluminum sheet, aluminum foil, and glass. The results showed that glass-type reflective material was more efficient as compared to aluminum sheet and aluminum foil. Sabiha & Rahman, (2020) performed a comparison of parabolic solar cookers using reflective materials such as glass, aluminum foil, and stainless steel. It was concluded that glass is a better reflective material compared to aluminum foil and stainless-steel sheets.

Cooking pot material can affect the performance of the solar cooker. Kumar & Singh, (2018) evaluated performance of the parabolic dish type using aluminum and galvanized iron sheet for cooking pot. The results showed that the time take to boil water in aluminum pot was less as compared to galvanized iron pot. The parabolic solar cooker has good thermal performance as compared to other types of solar cooker. M Akoy & A Ahmed, (2015) constructed and conducted performance evaluation of three types of solar cooker namely; box -type, panel type and parabolic type. The results showed that the parabolic type attained average maximum temperature of 86.5 ^{o}C, followed by box-type 52.36 ^{o}C, and panel-type 43.5 ^{o}C.

II. MATERIALS AND METHODS

A parabolic solar cooker was designed and fabricated at the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC) located at Arusha Municipality in Tanzania. The materials used for the fabrication of the solar cooker were bought from the local market. The materials used are flat bar, round bar, silicone sealant, cement, and fiber mold which was constructed to provide a parabolic shape. The surface area of the parabolic dish was $2.5m^2$. The focal length and depth of the parabolic cooker were 0.65m and 0.4m respectively. The reflective material used was glass which was cut into square pieces of 40mm length and 40mm width. The materials used for the cooking pot were aluminum, and the pot was black painted on the outer surface to absorb more solar energy. The instruments used for measurements include; thermocouples for measuring temperature, a pyranometer for measuring solar irradiance, a digital watch for measuring time, and weight balance for measuring the weight of the sample. Preliminary testing was conducted at CAMARTEC and further experiments were conducted in the central part of Tanzania in Dodoma and Singida Regions, the place which receives a sufficient amount of solar radiation. The photography of the constructed parabolic solar cooker is shown in figure 1.

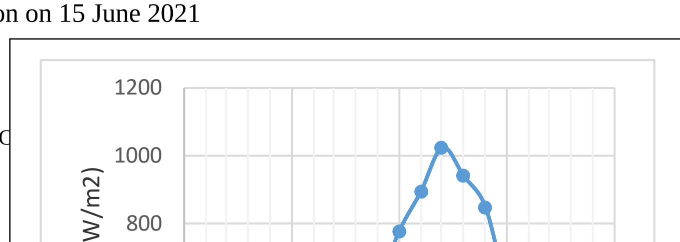
Figure 1. Photography of the constructed Parabolic solar cooker

III. RESULTS

The experiment took place in June 2021 in Dodoma and Singida regions. The experiments began at 7:00 am and continued until 6:00 pm during sunset. The average sun irradiation ranged from around 10 W/m2 to 1060 W/m2 and the minimum irradiation was observed during the starting and closing of the experiment whereas the maximum irradiation was observed around noon. The cooking substances tested were water, meat, and beans. The procedure used to test the thermal performance of a parabolic solar cooker consists of determining the time used for heating one little of water to the boiling point as well as the time used for cooking one kilogram of beans and meat. The records were taken after every one minute and the average value was calculated. The average solar radiation recorded during June in Dodoma region is shown in table 1. The average maximum temperature achieved was 121°C. The data collected during experiments for June 2021 is shown in tables 2,3 and 4 for water, meat, and beans respectively. Water boiled at 95 °C and then the time taken to boil one liter of water was 15minutes. The time taken to cook meat was 50minutes, whereas the time taken to cook beans was 90 minutes as shown in Tables 3 and 4. Table 5 shows the summary of the cooked substances.

Table 1. Solar radiation in Dodoma Region on 15 June 2021

Time(hrs)	Solar



http://dx.doi.org/10.29322/IJSRP.12.06.2022.p12619

	Radiation(w/m2)
7:00	155
8:00	394
9:00	606
10:00	776
11:00	893
12:00	1025
13:00	939
14:00	848
15:00	587
16:00	316
17:00	214
18:00	56

Table 2. Data for boiling water recorded during experiment on 16 June 2021

Time (Min)	**Water Temperature (°C)**	**Irradiance (W/m²)**
0	18	676
1	21	690
2	25	702
3	29	695
4	35	710
5	41	740
6	48	782
7	54	802
8	60	790
9	68	671
10	71	689
11	79	712
12	83	789
13	89	823
14	93	855
15	95	887

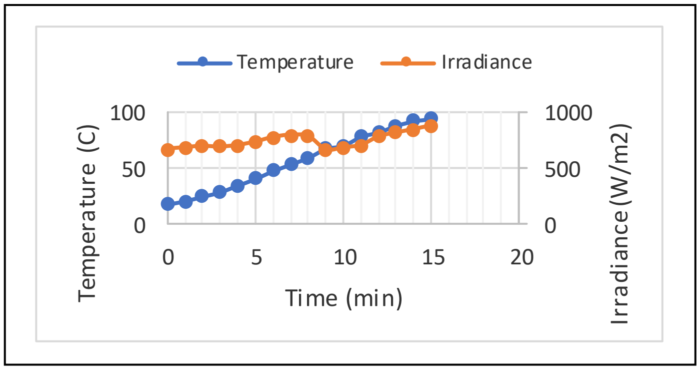
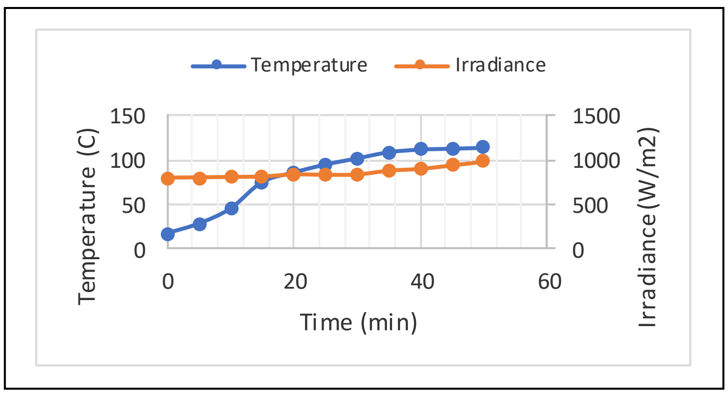


Table 3. Data for cooked meat recorded during experiment on 17 June 2021

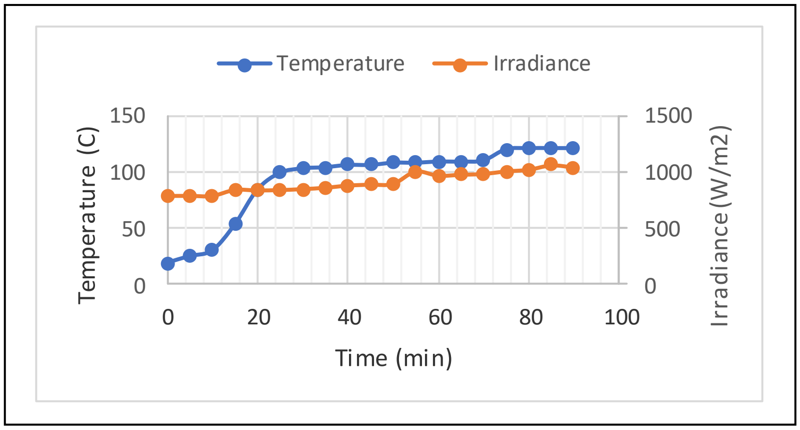
Time (Min)	**Temp of the cooked beans (° C)**	**Solar radiation (W/m²)**
0	17	796
5	28	800
10	45	805
15	75	810
20	86	835
25	95	831
30	102	834



35	109	881
40	112	903
45	113	945
50	114	990

Table 4. Data for cooked beans recorded during experiments on 17 June 2021

Time (Minutes)	Temp of the cooking beans (°C)	Solar radiation (w/m2)
0	19	780
5	25	781
10	30	780
15	53	835
20	84	831
25	99	834
30	103	843
35	104	855
40	106	875
45	106	884
50	108	890
55	108	1003
60	109	966
65	109	974
70	110	982
75	120	1005
80	121	1020
85	121	1060
90	121	1042



S.No	Cooked substance	Unit	Quantity	Average time taken (min)	Remarks
1	Water	litre	1	15	Boiled
2	Meat	kg	1	50	Cooked
3	Beans	kg	1	90	Cooked

IV. CONCLUSION

Based on these results it can be concluded that the tested parabolic solar cooker can be used as alternative cooking technology for cooking different food, especially in regions that have high potential Solar radiation. The solar cooking technology is environmental friend, affordable, and can reduce energy costs, especially in the current situation when the oil price is becoming too high. Despite its enormous advantages, this technology is not well known to people. Therefore, special effort needs to be done to disseminate this technology to the people, especially in areas with high potential for solar radiation.

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