



Effect of Height Variation for the Determination of Accurate Focal Zone for a Thin Foil L-Shaped Parabolic Reflector

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ABSTRACT

The use of concentrators in forms of solar energy collector in order to concentrate sun rays for better usage is on the increase worldwide. This paper presents the effect of height variations for the determination of accurate focal zone for three different parabolic reflectors. The system was constructed using locally available materials with design parameters. The thermal performance experiments were conducted (water boiling test) to evaluate the performance evaluation of the reflector at different height. The experimental test results showed that the systems when set at 65 cm height from cooking vessel performed better than at 45 cm and 55 cm heights respectively. Similarly the temperature profile of the systems showed highest result of 94.1 °C at a height of 65 cm.

Keywords: Solar reflectors, Solar cooking, Parabolic collectors, Focal zone and Temperature profiles.

1. INTRODUCTION

Energy is one of the most important factors in social and economic development of a country. Energy demands across the world have been on a rapid rise recently due to population growth and industrialization. It is obvious that the conventional energy sources are under increasing demand and there is a need to examine alternative sources to augment these energy sources (Sadiket *et al.*, 2013).

The rate at which our environment is being exposed to global warming, ozone layer depletion and desert encroachment as the result of human interference cutting down trees for energy needs for cooking is alarming in the developing world. Apart from the CO₂ released to the environment, the use of fuel wood is causing desertification and other ecological degradation which drastically affects the land fertility (Schwarzer and Silver, 2003).

Theoretically, solar energy has resource potential that far exceeds the entire global energy demand (Govinda *et al.*, 2011). The necessity for an available alternative source of energy to replace or supplement the use of fire

wood for cooking food cannot be over emphasized, solar energy offer possible solution to these problems. One of the practical applications of solar energy is to harness it for partial cooking needs of the people living in area blessed with abundant sunshine, like Nigeria. The solar cooker if available and suits cooking requirements efficient can offer partial solution to the multitude of cooking problem faced by the people (Nuhu, 2012).

Solar energy can be applied in different ways and also many different methods for collecting the solar energy from incident radiation are available performance vary depending on how much solar energy is available at the site and also on the determination of the focal zone which is obtained by varying the height of the cooking vessel. Literatures have shown that concentrating or focusing types of solar collectors are much older than flat plate collectors (Abdulrahimet *et al.*, 2010).

This study presents findings on the effect of variation of heights on the determination of focal zone for optimum performances of differ

configurations of solar parabolic concentrators for cooking applications.

2.0 Materials

The materials used for the systems construction were locally available materials which includes; Plywood of 1.5 cm thick 1.23 cm thickness, Soft wood Plank of 2.5 cm thickness, assorted wire nails, Glue adhesive, Gloss paint, Thin foil paper and Aluminum cooking vessel (painted mat black paint).

2.1 Methods

2.2 Construction procedures

Solar parabolic reflecting systems were constructed from an improvised selected materials consisting of; geometrical designs L shape and U shape using plywood and planks joined together to house the reflective materials. The reflective surfaces were covered with strips of reflecting mirrors and thin foils reflecting surfaces. The parabolic concentrator was designed to house both the cooking vessel and an integrated parabolic concentrator which enables varying the focal length at different height. The system also enable variation of the parabolic collectors at stand that of dimension 62 cm × 62 cm and thickness of 1.5 cm. the cooker has a table which served as a cooker stand with positioning hole where cooking pot or cooking vessel can be placed, the cooker stand has an opening space at the bottom which allows the cooking pot or cooking vessel received solar radiation on its lower side with help of Thin-foil reflecting surfaces, L-shaped parabolic reflector placed at the bottom of the cooker stand.



Plate 1: Constructed parabolic concentrated solar cooker

Plate 1 presents the photograph of the improvised mirror parabolic solar cooker, showing the system stand, cooking vessel and indicating flexibility of varying the concentrating surface up and down focusing to attain optimum solar reflectance towards the cooking vessel. The thin foil L-shaped parabolic reflector also used to direct solar radiation to the bottom of the cooker in section of linear parabolic concentrator and was placed directly at the bottom of the cooker supported by cooker stand.

The main basis of parabolic reflectors or concentrators is that it takes the advantage of every rays of light coming from infinity and concentrated at it focus (Escobaret.al, 2011). Therefore, the focal point of the reflector at various heights was determined using equation (1) bellow (Basil et al., 2013)

$$x^2 = 4fy \quad (1)$$

Where. x is the half of the total length of the parabola (cm), y is the height of the parabola measured from the base (cm), f Focal point (cm). In line with the above equation, the focal points of the presented solar concentrators were determined at different height.

2.3 Heating procedure

The developed parabolic concentrating solar cooking system, concentrates solar radiation to a varying different heights of the parabolic concentrator. Heat gains accumulate and transfers to the cooking vessel thermodynamically resulting into rapid temperature increase especially when the collectors are tracked following the movement of the sun. Solar radiation is focused toward the focal point where the cooking pot is held or placed and the cooker requires frequent adjustment toward the sun. The thin foil paper L-parabolic reflector concentrates light and heat from the sun in small cooking called focal zone, making the energy more concentrated and increased its heating power.

2.4 Experimental set up

Experiments were performed and thermal performance analyses of the parabolic reflecting systems were varied at different heights. Parameters measured were temperature, water

heating evaluation test and systems efficiencies were adequately evaluated. Among the instruments used include; Digital thermocouple data loggers to measure temperature at different points, Anemometer to measure wind. Mercury in glass thermometer, Pyranometer to measure global solar radiation. The performance of the system was based on the following parameters required generated temperature of the water. The distances between reflector and cooking vessels were measured and recorded at 65 cm, 55 cm and 45 cm heights. The significant of varying the distance h was to determine the effect of height variation for the optimal system performances. The cooker was positioned to track the incident solar radiation of the sun; the thermometer was placed inside the pot containing 750 g of water. Different temperature values were measured and recorded at 30minutes interval. Also the distance between cooking vessel and reflector of the cooker were measured at 65 cm, 55 cm and 45 cm.

3.0 Results and Discussion

3.1 Thermal performance tests (Water boiling test)

The thermal performance test was carried out for the three reflectors set at 65 cm, 55 cm and 45 cm respectively; this was done to obtained cleared and appropriate focal zone. The results obtained were given Fig 1.

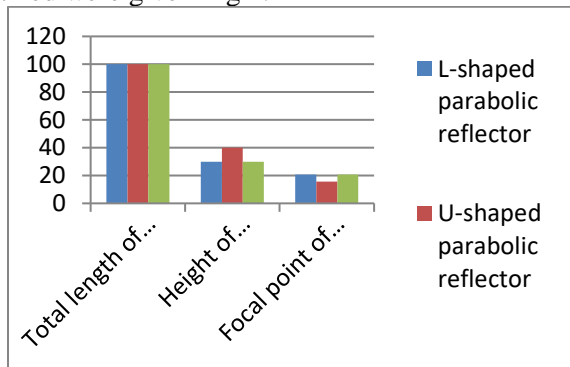


Figure1: Measured values of focal points of the three reflectors

The thermal performance experimental results of the system were presented in Figures 2, 3 and 4 for systems fixed at 65 cm, 55 cm and 45 cm height from cooking vessel to reflector respectively.

Figure 2. Shows that, the highest recorded temperature of the cooking vessel, the corresponding global solar radiation and wind speed were 94.1°C, 867 W/m² and 1.12 m/s respectively set at 65 cm. This shows that the temperature of the cooking vessel water temperature T_{CV} and ambient temperature continuously increased to a maximum temperature value, as the corresponding wind speed and global solar radiation gradually decreased.

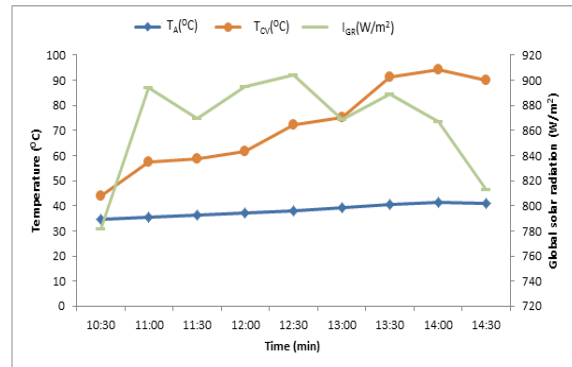


Figure 2: Pot temperature variations at 65 cm height

On the second day as shown in Figure 3, the highest temperature of the cooking vessel, the corresponding global solar radiation and wind speed were 73.1°C, 982 W/m² and 1.11m/s respectively This was done with distance between L-shaped thin foil parabolic and cooking vessel (h) set at 55 cm. The Figures shows that, the temperature of water contained inside cooking vessel T_{CV} continuously increased with gradual increase of ambient temperature, wind speed and corresponding global solar radiation. The temperature of the cooking vessel and ambient temperature gradually decreased to a certain value as the wind speed continuously increased, this was a result of gradual decreased of the intensity of solar radiation.

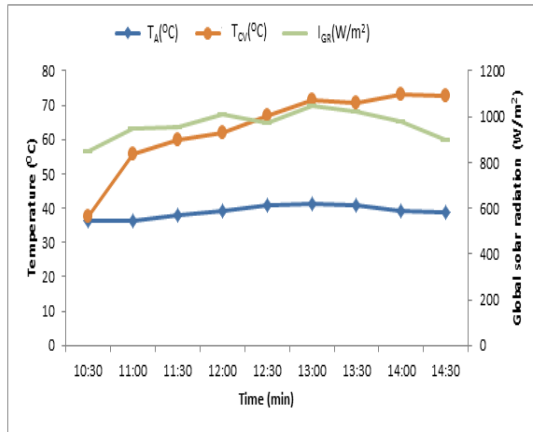


Figure 3: Pot temperature variation with time and corresponding global solar radiation at 55cm height

Similarly, Figure 4. Shows that, the highest water temperature recorded inside cooking vessel, the corresponding global solar radiation and wind speed were 74.9 °C, 864 W/m² and 1.68 m/s respectively. The reflector collector towards cooking vessel was set at distance of 45 cm. Figures shows the water temperature and ambient temperatures continuously increased as the corresponding wind speed gradually decreased, while the global solar radiation was increased. By 13:00 pm to 14:30 pm the water temperature, ambient temperature and wind speed decreased, this could be as a result of decreased of global solar radiation due to cloud covered the intensity of solar radiation.

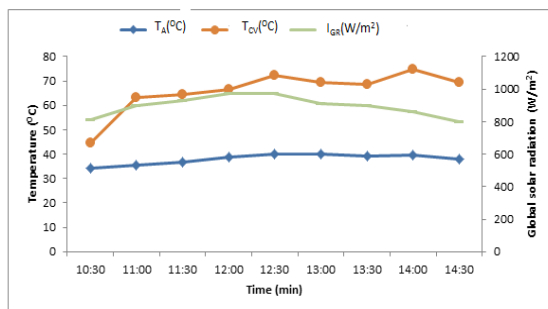


Figure 4: Pot temperature variation with time and corresponding global solar radiation at 45cm height

5.0 Conclusions

The experimental tests conducted of the developed systems were varied at 65 cm, 55 cm and 45 cm from cooking vessel to reflector of the concentrating solar cooker, the results

obtained showed that the cooker set at 65 cm was able to produce a water temperature of about 94.1 °C, while that at 55 cm and 45 cm attained the maximum temperature of 69.4 °C and 72.8 °C respectively. This shows, that the variation in height between the cooking vessel to concentrator play a major role in the determination of accurate focal zone, that gives maximum efficiency.

6.0 Recommendation

The results obtained through the evaluation of height variation in determining focal zone of the developed systems shows the attainment of the minimum temperature requirements for cooking applications at the optimal focal length. Despite the limitation of uninterrupted reflecting surface of the collector we wish to make the following recommendations;

1. Further research need to be carried out for an improved automatic tracking device system to ease the operation of the system and also increases its performances efficiency.
2. Selection of high emissivity reflecting material and further losses reduction need to be carried out.

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