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Maximizing energy harnessing in solar ovens to use environmentally friendly energy: Material and angle of inclination

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Abstract

Non-renewable energy, such as fossil fuel, has been the traditional way of providing power. What has alarmed the global public is that these non-renewable resources are fast depleting and are harming the climate because they cannot be converted to clean power. The conversion of non-renewable energy into other forms of energy results in the emission of harmful gases such as greenhouse gases (i.e. carbon dioxide and methane). Other toxic gases released include benzene, which is cancer-causing and nitrogen oxides which contribute to photochemical smog. To reduce these effects, innovations on clean and renewable energy have recently emerged as an alternative way of providing sustainable environmental energy. One of them is solar energy, which is defined by the Comprehensive Guide of Solar Systems as the use of the sun's energy either directly as thermal energy using photovoltaic cells in solar panels or transparent photovoltaic glass to generate electricity [8]. According to research, it is one of the most efficient and readily available sources of energy for the inhabitants of the earth [9]. This paper reports on how a solar oven can be home-made, using cheap and readily available materials in the quench of using clean and renewable energy as an alternative to harmful fossil fuels for baking. We compared the heating effect of three readily available aluminium composites. We also analyzed the compromise angle of inclination of the reflectors for maximum possible energy harnessing to increase the efficiency of the solar oven. The analysis is statistically based and was examined using a 0.05 significance level.

Solar Oven | inclination | reflective panel | aluminium | prototype

Abbreviations: ANOVA, Analysis of Variance.

Introduction

With the growing population of the world, the pressure on global energy resources has increased. Fossil fuels have overtaken the market for a long time. Among other places, they are also used in rural areas and developing countries, though the overall emissions of rural areas in developing countries are comparatively low. Fossil fuels emit harmful pollutants into the atmosphere when they are burnt, which leads to air pollution and global warming [1]. Such effects have brought into existence international bodies such as the United Nations Environmental Programme. They now focus on limiting warming to specific levels of global mean temperature, such as 2°C or 1.5°`C [2]. To ensure nothing less than human survival, scientist and engineers need to formulate alternative renewable energy resources with immediate action.

Everyday activities, such as cooking could be instrumental in generating technologies that reduce emissions. Cooking, after all, is one activity that humanity cannot live without because its survival depends on food. According to Betts et al. [5], about two million metric tons of firewood and charcoal are consumed daily in developing countries. Mostly the cooking is done on open fires, which leads to low fuel efficiency and high pollution emission. Inhabitants of rural areas mostly burn fuels and charcoal in poorly ventilated rooms, which exposes them to harmful gases. Women and children are most affected

The gases emitted contain carbon dioxide, which is detrimental to the health of the users as well as the environment in which they live. Diseases and conditions such as acute respiratory infection, low birth weight in pregnant women, among other ailments, have become very rampant in developing and rural areas where charcoal and firewood are used as a source of heat for cooking [5]. Solar cooking provides a better option for using charcoal and firewood as cooking fuel. It is environmentally sustainable as it uses clean and renewable energy. Solar cookers might not entirely solve the issues of global warming and

deforestation, but solar cooking is a better way of reducing the amount of carbon emission into the atmosphere. It never runs out, and it is a natural source.
Moreover, it creates jobs for rural immigrants since the maintenance of some of the solar appliances requires a vast workforce [6]. Solar cooking has become one of the world's best and most exciting solutions to problems associated with the rural way of cooking, which involves the burning of fuelwood sources and other environmental issues related to wood. In the findings of a study, Droege highlights fuelwood as a crucial source of energy in households. The study found that homes of more than six inhabitants require more fuelwood. Since a majority of the respondents were unemployed or low-income earners, they need an alternative efficient but cheap source of energy to cook [7].

A solar oven is a device that helps harness and utilizes direct sunlight energy to warm foods and drinks. It can be used in places where there is much sunshine, such as Africa, which is in the tropical zone. It requires minimum technical know-how to build and is most suitable for developing countries and rural areas where electricity is scarce. It is useful because it has moderate temperatures which would retain the nutrients in the food. Finally, health hazards such as irritation to lungs and eyes are avoided as cooking is smoke-free. Solar ovens come in various forms and have three major parts. The feature common to each oven design is the shiny reflective surface that directs the sun's rays onto a dark cooking vessel.

For this project, we aimed at designing and constructing solar cookers to compare the reflective index of aluminium composites on the heating effect of the solar oven. Also, we analyzed the angle of inclination of the reflective surface/plate relative to the horizontal ground to get the best design of the solar oven that can harness the maximum amount of heat energy per day. The degree of inclination determines the amount of sunlight that will effectively heat the oven.

Methods

Three identical solar oven prototypes were made using aluminium, aluminium foil and alucobond to create the reflective material as shown in figure 1(a). All the aluminium composite sheets had the same dimensions and were all shined on the surfaces.

Varying reflective material

The angle of inclination of the reflective plate was kept constant at 45 degrees for the three prototypes (see figure 1(c)). Three identical containers were then filled with 50 millilitres of water, and the initial temperature of the water was measured using the temperature probe. The containers were placed inside the prototypes, and the top was covered by a transparent glass to minimize heat loss to the environment. The three ovens were then taken outside and placed on the same position, where the light intensity was approximately equal to allow exposure to the same intensity of sunlight (figure 1(e)). After 25 minutes, the final temperature of the water in the containers was measured using the temperature probe (figure1(c)). The procedure was repeated six times to get six temperature values for each sample.

Varying the angle of inclination

The angle of inclination is defined as how much the reflective surface is raised relative to the horizontal base. It was measured from the horizontal plane of the oven to the flat surface of the reflective plane (figure 1(d)). Two angles were used (45 degrees and 80 degrees). The first angle was set to 45 degrees on all the ovens, and six sets of temperature values were taken over in 25 minutes. The angle was then changed to 80 degrees, and six temperature values were taken for each prototype. The average temperatures were then calculated.

Data collected

Two sets of temperature data were collected based on the varying the angle of inclination. Six data points were collected for each prototype, and the averages were used for statistical analysis.

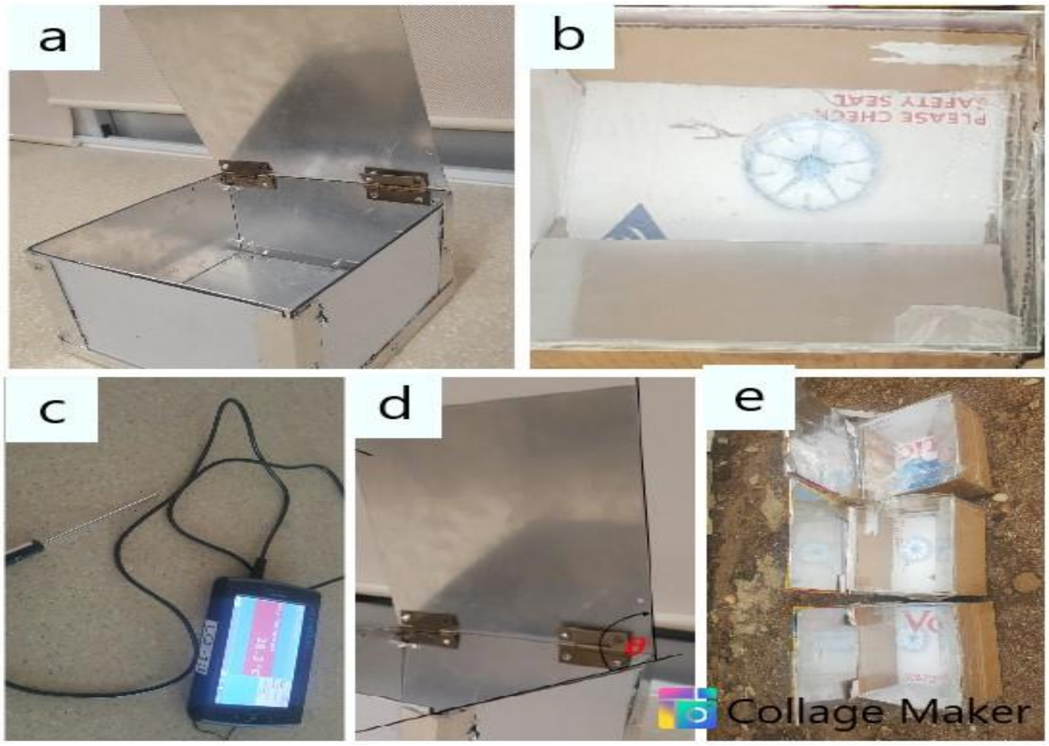

Fig. 1. (a) the completed prototype (b) the container with the water inside the oven. (c) the temperature nob used with a lad Quest (d) depicts how the angle was measured relative to the reflective panel (e) the three prototypes were placed on an open space

Results and Discussion

All the statistical analysis was done using R studio at the 95% confidence interval. We first conducted a normality test to determine whether to use parametric tests or not.

Test for normality

The test was done on the six data points for each material on the prototype with Shapiro package. Shapiro is a statistical package in R studio, that is used to test if the data follows a normal distribution. The test was carried out for both the data on different materials and data on different angles of inclination. All the p values for the test were greater than 5%, indicating that there was no statistical difference, thus the data followed a normal distribution (at 95% ci)

Table 1. The results of the Shapiro Test

Material	**p value**	**norm distribution**
Aluminium high carbon	0.2362	Yes
Alucobond	0.1002	Yes

Aluminium foil	0.1331	Yes

ANOVA test

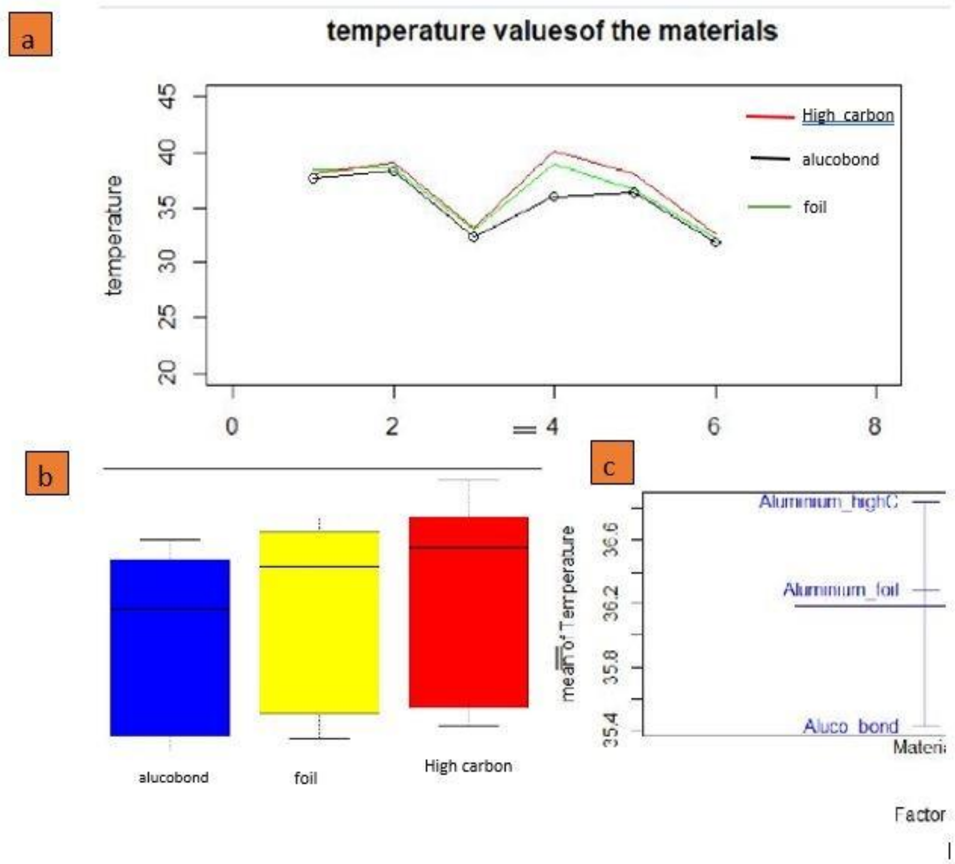

Fig. 3. **(a)** the line graph showing the distribution of temperature values for each material **(b)** the box and whisker plots for the data **(c)** graph showing the distribution of the mean heating values for the materials.

One-way ANOVA test

We carried out an Analysis of Variances (ANOVA) test to test the difference between the mean heating effect of different materials. In this test, we had only one factor, the material and one level of the angle of inclination of the panels. The response was the maximum temperature recorded in the oven for each material. The table below shows the summary of the one-way ANOVA.

Table 2. The hypothesis

H_0	H_a	**Result**
$\mu aluco = \mu foil = \mu highC$	$\mu aluco \neq \mu aluco \neq \mu aluco$	accept H_0

At the 95% confidence interval, the p-value of 0.709 > p-critical of 0.05, showed that there was no statistical difference between the mean heating effect of the different aluminium composite materials. This result meant that the three materials produced the same heating effect statistically. Thus, we used a non-statistical judgment to choose the best material on which to vary the angle of inclination. Aluminium foil was selected because of its affordability and portability. It is also practical in the construction of the oven. We went on to perform a two-tailed student t-test on the two angles for aluminium foil.

Two-tailed t-test

The heating effect produced by the two angles was statistically compared at the 95% confidence level. This confidence level is ideal for a device that would be used for non-medical purposes. T-test was used because our sample size was less than 30, and the population variance was unknown.

Table 3. The hypothesis

H_0	H_a	**Result**
$\mu 45deg = \mu 80deg$	$\mu 45deg \neq \mu 80deg$	rejected H_0

After the test at 95% confidence interval, the p-value(0.009323) < p-critical(0.005)), meant that there was a statistical difference between the heating effect produced by a 45-degree angle and the one produced by an 80-degree angle. Eighty degrees had a higher heating value than a 45-degree angle.

Conclusion

There was no statistical difference between the average heating temperatures of the aluminium composite materials used. Based on our experiment, we concluded that the three materials had the same heating effect. Since they all have the same heating effect, we recommend the use of aluminium foil in rural areas, since it has the least cost and an average life span. However, those willing to pay the high price may use high aluminium carbon, which requires more experienced personnel to cut and has the longest life span. There was a statistical difference between the heating effect of the two angles with the 80-degree angle having the more excellent heating value than 45 degrees. Based on our design, we recommend that in the construction of solar ovens, the angle of inclination of the reflective surface should be between 70 degrees and 80 degrees. Users of solar ovens should position their oven in an open space to harness maximum solar energy at any given time.

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