Comparative study of two different reflectors, zincalume steel and aluminum foil tape in the application of solar cookers

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Abstract. The amount of energy resources from fossil fuels continue to decrease, these lead to high demand for renewable energy. One of the biggest energy resources in our nature is solar power. A solar cooker is a device that uses solar power to cook a meal. The performance and temperature of solar cookers depend on the material we use in the device. One of the most important components in solar cooking is reflector because solar cookers use a mirrored reflector to collect and transfer sun rays into the cooking pot to increase the temperature inside the pot. This paper compares two different materials as a reflector in solar cookers. The first reflector is aluminum foil tape, these materials are very cheap, light, easy to use so it could be applied in many designs. The Second reflector used was zincalume steel, it has the highest reflector among other thin steel available in the market. The design of panel reflector from aluminum foil tape was 4 rectangular and the design of zincalume steel reflector similar to cone. The performance of two different reflectors has been analyzed in Solar cookers used to boil 500ml water for 120 minutes. Water temperature from the first and the second reflector showed a similar result. It showed that reflector made from aluminum foil tape and zincalume steel has similar reflectivity.

1. Introduction

In Indonesia, many households use petroleum gas as the main fuel to cook, but the gas comes from fossils which are in danger of extinction. Moreover burning petroleum gas produces carbon dioxide as known as a greenhouse gas which is the main element contributing to global warming. Therefore we must use the new energy resource to replace fossil fuels [1]. The most powerful and free energy in our nature is sunray. Many researchers already used sunrays as renewable energy. Indonesia is placed in the equator, thus it can get enough sunray through the year with average power radiation of 4.8 kWh/m^2 for 8-10 hour per day[2][3].

The utilization of solar power to replace petroleum gas was to cook with solar cookers. Solar cookers are the device that uses sunlight as fuel to cook the meal [4]. Solar cookers use free energy from the sun, so it's cheaper and cleaner because it didn't release carbon dioxide [5]. Despite the low cost and clean state, solar cookers used a longer time to be cooked than conventional cookers [6]. In many developed countries such as Indonesia, people are still reluctant to use solar cooking due to the long time to cook and the strong radiant from the sunray which made it uncomfortable to cook.

This paper tried to make a solar cooker with a design to avoid strong radiance so that people can be more comfortable using it. Instead of using a common design with direct and reflected sunlight, these cookers used a trapezium reflector to guide the sunray into the base of the cooking tray. Without the direct sunlight and the cover above the cooking tray, the user of solar cookers can cook with more ease because the reflected sunray (which usually gives a strong dazzle to the eyes) transfers directly under

the cooking tray [7]. Another object analyzed in this paper is the reflector panel. One of the most important components in solar cooking is the reflector because solar cookers used a mirrored reflector to collect and transfer sun rays into the cooking pot to increase the temperature inside the pot. This paper compares two different materials as a reflector in solar cookers to get the best yet cheap material for solar cookers.

2. Principle of Solar Cookers

Solar cooker is a device to convert sunlight into heat then used to cook the meal in the tray/pot[8]. These devices used a concentrator or reflector to collect sunray and transfer direct/indirectly into the cooking pot[9]. There are many types of solar cookers, based on concentrating/reflector there are three categories which are the most popular and used widely. As we can see in fig.1, the three solar cookers are solar cookers box type, panel type and parabolic type[10]. Solar cooker box type has a similar design with an oven, mostly the rectangular type with or without an additional reflector panel. Solar cooker panel types are almost similar to box type, but it came with more various designs (not always rectangular) and there is an addition of panel reflectors to enhance the performance of solar cookers. Parabolic solar cooker mostly used a parabolic panel and put the cooking pot right on top of it.

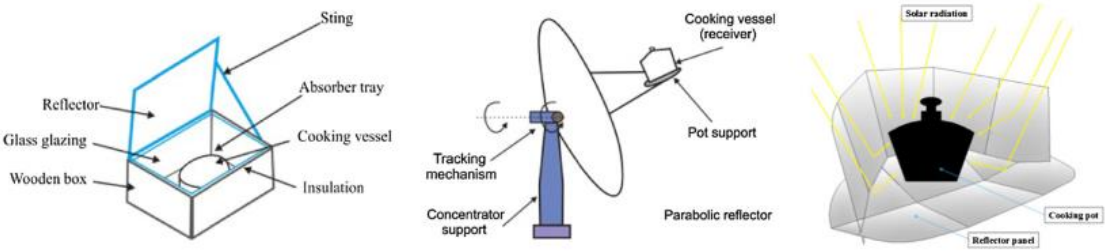

Figure 1. Direct solar cookers: with box (a), parabolic (b) or panels [11] .

Among these three, parabolic solar cookers showed the highest temperature, but the design of parabolic solar cookers makes it difficult for the user because of strong radiance. Meanwhile, box type and panel solar cooker perform lower temperature than parabolic type, but are user friendly because the radiant is not as strong as the parabolic type. Therefore people prefer used box type or panel solar cookers to use daily in their household. Apart from the shape of the reflector, the material used as a reflector and the shape of the reflector (inclined wavy or flat plate) play an important role in order to reach good performance in solar cookers [12]. Hence in this paper, we used two different reflectors from two different materials with a slightly different shape but a similarly large area.

3. Design and Method

3.1. Design

The solar cooker is made from wood and all the skin on the surface is painted black to absorb more heat (see fig.2). The design of these solar cookers inspired by [7] with the same purpose, to create a low-cost solar cooker with high performance and easy to use. These devices used two different reflectors, the reflector panel design like Prisma trapezium (as seen in fig.2b) with two big rectangles 4620 cm^2, two rectangles 2310 cm^2 and four triangular 1155 cm^2. The panel reflector is made from thin wood and coated with aluminum tape. The second reflector used zincalume (alloy of 55% aluminum and 45% zinc) with a design similar to cone but without the top. The half-cylinder reflector is employed as a connector from the reflector panel and cooking tray and used to reflect the sunray from the panel reflector into the tray. The cooking tray is made from stainless steel with the bottom tray paint tint black to prevent the reflection from stainless steel and to absorb more heat.

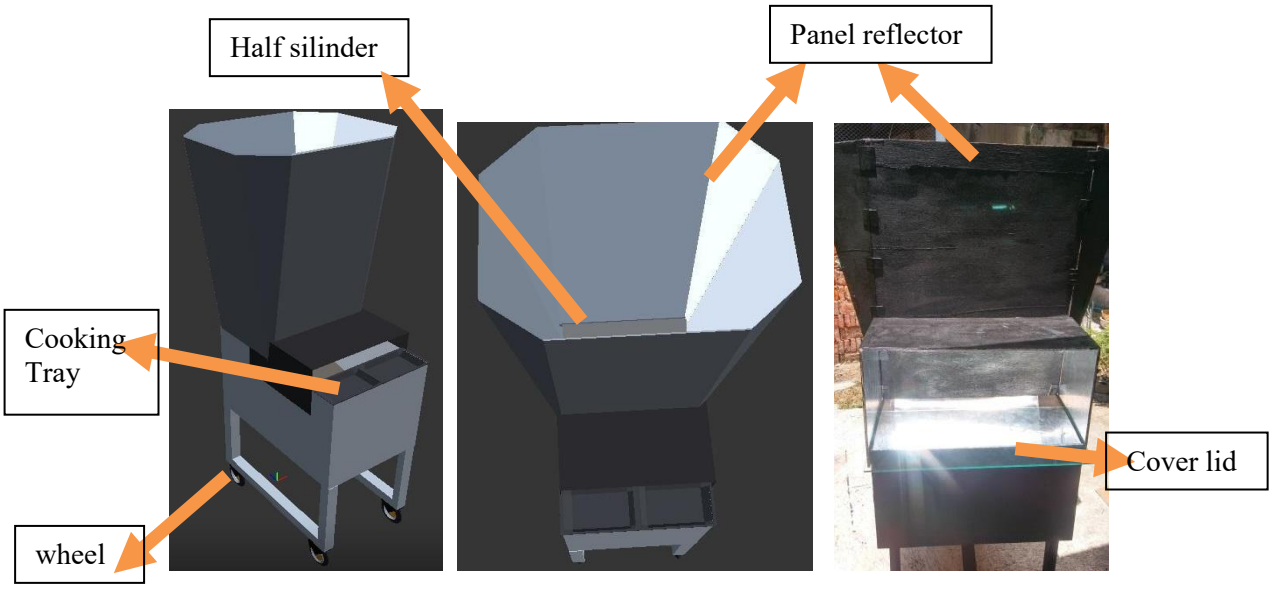

Figure 2. Solar Cooker, a). Figure from side, b). Figure from above, c). Up front of solar cooker with mirror cover lid

One of the factors for solar cookers to reach high temperatures is heat loss such as using the lid to prevent evaporation from the cooking tray. The lid (see fig.2c) used in this device is made from a mirror with a size of 30 x 60 cm to cover the tray. Even though Indonesia gets enough sunshine all year, the sun has its own move. The sun's move from west to the east makes it difficult to track the ray source for these solar cookers. The device is designed to be used in a household with limited sunlight due to many barriers such as a wall or trees. Therefore these solar cookers are given four wheels, thus it can easily be moved around to find a better angle and place for more sunray. This paper design with the purpose to make the user can be cooked more conveniently, thus the panel reflector is not directed to the cooking user. Instead, the user got in the shadow from the panel reflector and did not get direct strong radiation from the sunray.

3.2. Experimental Set Up

The experiment was already done in the backyard to represent real-life with many trees and the surrounding wall. The solar cooker used to heat water for 120 minutes between 09.00 am and 11.00 am. Power radiation of sunray and temperature of the water had been collected manually every 5 minutes. The device to measure radiation was lux meter to and solar power meter, meanwhile an infrared thermometer gun has been used to measure temperature in water. The size of the cooking tray used in this experiment is 31 x 25 cm, the tray fills with 500 ml water. There is only one kind of solar cooker used in this experiment, thus the performance of reflector panels with aluminum and zincalume has been measured on a different day. After solar cookers with reflector panels with aluminum tape were measured, the panels were replaced with cone panels made from zincalume. The data collected many times to get the humidity, radiation and temperature surrounding as similar as for those two reflector panels.

4. Result and Discussion

The first reflector to be evaluated was a reflector based on aluminum tape. The shape is similar to trapezium in hope, the angle between the plane can trap and reflect more sunray. From the result (see fig 3.), the highest temperature performed by aluminum tape reflector was 75.9°C. Meanwhile, the reflector made from zincalume got 72°C as maximum temperature. The result showed that reflector based on aluminum tape perform better than reflector based made from zincalume.

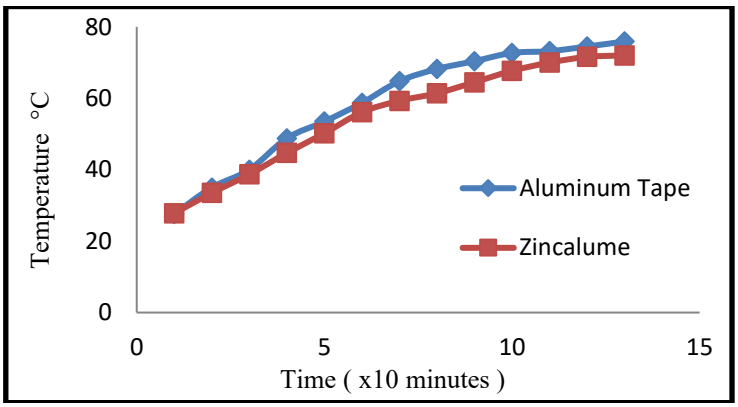

Figure 3. Comparative performance of two reflectors, aluminum tape and zinalume.

From table 1, we can see solar radiation and illumination when the experiment happens. Even though the two data collect on a different day, the number of solar radiation and illumination show similarity. It is safe to say the two reflectors were analyzed in the same condition. In table 1, we can see that the stronger radiation temperature of water increases faster. When the radiation gets weaker, the temperature inside the water increases slowly because there is a lack of heat absorbance in these devices[13]. When solar radiation is not too strong, with the help of solar absorbance the previous heat can be stored safely so that when the heat from the sunray gets weaker there is still the heat from storage to backup so that the temperature does not decrease. On top of that, the experiment only allows taking data until 120 minutes because above 11.00 am the sun changes its position, and with many trees and walls between it is hard to get the maximum amount of the sunray. Moreover, when water reaches a temperature higher than 80°C, the temperature tends to decrease because different temperatures between lid and water makes different heat transfer coefficients decrease, it makes calor in water decrease too [14].

Table 1. Performance aluminum tape and zincalume as reflector with solar radiation

Time (Minutes)	Lux	Solar Radiation (W/m^2)	Aluminum Tape (°C)	Zincalume (°C)	Solar Radiation (W/m^2)	Lux
0	154.7	1096	27.6	27.8	897	148.6
10	150.9	1172.7	35	40.5	1020.9	155.2
20	144.7	1191.5	40	48.7	1132.4	153.1
30	152.6	1097.3	48.8	51.3	1029.8	150.7
40	145.5	1052.4	53.5	56.5	939.3	149.5
50	147.2	1211	58.7	58	1007.9	150.2
60	149.7	1081.2	64.8	59.3	1064.5	155.1
70	143.3	1079.3	68.2	60.4	987.4	151.4
80	150.7	1132.8	70.4	62	1079.2	153.2
90	155.6	1018	72.7	68.7	1056.9	145.4
100	151.4	1099.6	73.2	70	1107.3	152.1
110	148.9	1067.5	74.5	71.6	1098.6	147.6
120	145.8	1126.5	75.9	72	1166.2	152.1

Cooking power and efficiency from this device can be calculated using questions 1 and 2[15]. With P is cooking power in W, is a range of temperature, t is time to heat the water, is mass of water (in this case the mass of water is 0.5 kg), is water heat capacity, I is solar radiation and A is heat absorber area.

$$P = \frac{\Delta T}{t} . m_{a.} C_{a.} \quad (1)$$

From question 1, we can see that the solar cooker with a reflector from Aluminum Tape got 14.08 W cooking power. Meanwhile, cooking power with a reflector from Zincalume got 12.89 W.

$$\eta = \frac{P}{I_T A_c} \, x \, 100 \tag{2}$$

The efficiency solar cooker calculated with question 2 for reflector Aluminum Tape is 16.37 % and for reflector Zincalume is 14.89 %. The cooking power and efficiency from reflector Aluminum tape is higher than reflector Zincalume, although the cooking power from these results tends to be lower than regular box type solar cookers [16][17]. Therefore the device needs many improvements to get better performance. The design has been successfully made the user cooking get less radiation, hence it made the cooking activity safer. Therefore the space from the connector made so much space, thus it caused much heat loss.

5. Conclusion

The comparative study of two different reflectors has been investigated. Reflective panels from thin wood coated with aluminum tape and trapezium design got higher temperature than the reflective panel from zincalume with half cone design. Maximum temperature reaches 75.9 °C for aluminum tape reflector and zincalume reflector reaches maximum temperature 72°C. The device needs many improvements to get a better performance such as the addition of a heat insulator and heat absorber to prevent heat loss so that it can enhance the temperature more quickly.

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