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Performance investigation of convex lens as light collector in low cost solar cooker

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Abstract. People all over the world always cooked every day, the fuel they used neither biomass, fossil fuels or firewood. All of these fuels had several problems, it can cause global warming and some of them nearly extinct. Solar cookers can be used to solve this problem. These cookers use solar radiation as fuel, so it won't be extinct. The device has been used in some developed country and successfully reduce pollution at a low cost. A minus point of solar cookers is, it was consumed a longer time to cook which caused many people to still prefer conventional cookers. This research tried to reduce cooking time in solar cooker by adding a convex lens as a light collector. The design of solar cooker used a common rectangular with a size 45 x 20 x 12 cm and three reflector panels attached. Various components like reflector, insulation and cover lid have been analyzed to created solar cookers with lower cost and better performance. Solar cooker builds from wood and the inner part is coated with black styrofoam for storage heat. Mirror and aluminum seal has been used as a reflector and the result showed mirror had similar performance with aluminum seal. Convex lens put directly on top of cookers lid, the pot with convex lens reach 5-8° C temperature higher than the one without it.

1. Introduction

Energy for cooking is the main energy consumption for households[1]. Most people used electricity and petroleum gas as cooking fuel, in a developed country they used firewood or biomass[2]. Petroleum gas (LPG) which most people used, was made from fossil fuels. Sadly, the amount of this material decreases rapidly and in danger of extinction. In Indonesia mainly in a rural area, many families used firewood as fuel to cook. As we know, firewood can produce smoke which not good for health. Moreover, high demand for firewood can lead to deforestation. These can cause global warming and damage the environment[3]. Indonesia is located on the equator, thus we can get sunray throughout the year. The abundance of solar energy and the clean production of solar cookers can be used to solve this problem. However, with so many advantages of solar cookers, this device has not been used widely. Lack of social acceptance, take a lot of space, slower cooking than another method, not available all the time is some factor that contributes to low acceptance[4].

Solar cooker is a cooking device using the heat of the sun directly as thermal energy. Common solar cookers are direct solar cookers with concentrators to reflect sunray into the pot. The most used and simple direct solar cooker is Parabolic Trough Concentrator (PTC) and Box Type Solar Cooker. PTC solar cooker performance high temperature, but the disadvantages from PTC has big size hence take a lot of places[5]. Therefore this type cannot be used in a small house with no yard which is common in a developed country. Another one is Box Type solar cooker, this type comes in many sizes and designs. Due to its simple design, Box type solar cooker can fit in any place. However, panel or box type perform



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lower temperature than PTC, thus it cooked slower[6]. Even though, one of the main factors, when people choose a device for cooking is time-consuming in cooking. With the demand to cook three or two meals a day, people need to cook efficiently. Therefore, to reduce cooking time, in this paper we used a convex lens as a light collector to enhance the performance of concentrator in Solar Cookers Box Type.

2. Description of solar cooker

A box type solar cooker take sun heat from direct sun ray which goes through the glass on top of box and sun heat from reflective panel[7]. Solar cooker box type consists of outer box, inner box coated with a thermal insulator, reflector, cooking pot and glass lid to prevent evaporation. The coming sunray falls on to the reflector and passes through it to cooking pots. The heat absorbed by the cooking pot and enhance the water temperature inside. The inner box is made from a thermal insulator to storage the heat from sunray. Glass lid on top of the cooking tray is used to heat loss and protect the cooking pot from dust and any microorganism outside.

The solar cooker used in this research is a simple Box type solar cooker made from wood with three reflectors attached and addition of a convex lens to enhanced performance. The outer box is made from isolator material to prevent heat loss. The inner box was coated with black isolator tape but later on it layered again with styrofoam paint in black for better heat storage. The panel reflector used two kinds of reflector, mirror and aluminum tape. The cooking pot used steel material as a better conductor and last, it was covered with a glass lid.

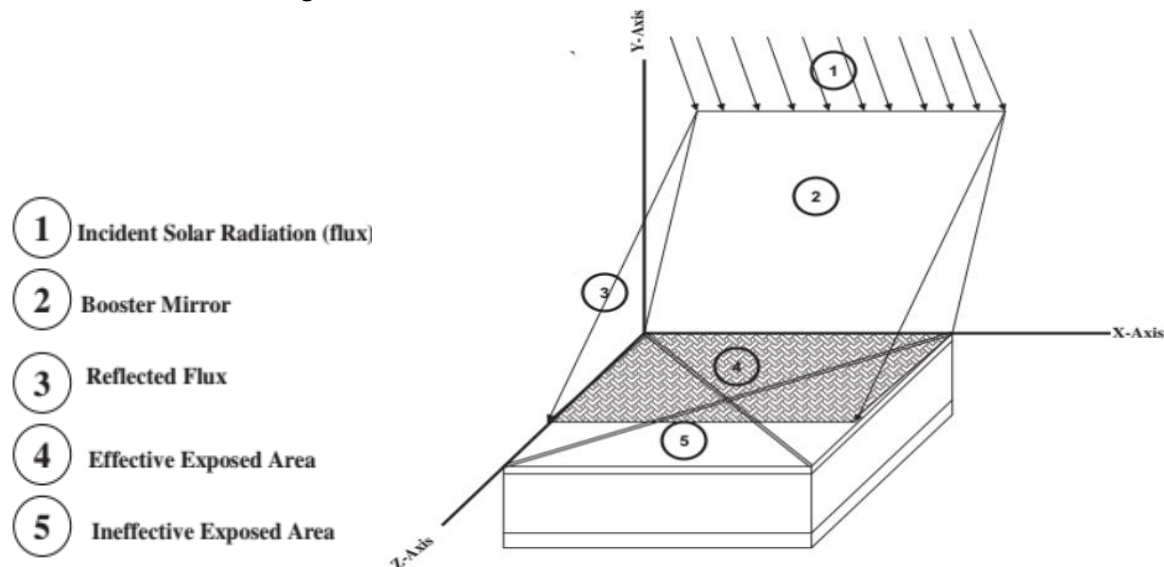


Figure 1. Scematic ray diagram of a box type solar cooker[8]

A common use of a solar cooker is to oven the meal and heated water. In this paper, we used a solar cooker box type to heat water. Solar disinfection is one of the easy ways to made drinking water. Solar disinfection involved storing water with transparent material and placed in direct sunlight for 8 hours or 1 hour if water temperature exceeds 50°C [9]. Moreover, water disinfection with solar cookers is a perfect combination because low-temperature sterilization water is an important step to kills any bacteria in drinking water. The effective temperature to eliminate bacteria in water range from 55°C to 65°C[10]. Therefore this paper focus on using solar cooker to sterilization water with low temperature.

Solar cookers box type usually performance lower temperature than solar cooker with a parabolic reflector. However, many people prefer to used solar cooker box type because it is easier and more simple than the parabolic type. To enhance temperature in solar cooker box type, we used a convex lens

as a concentrator. According to Valmiki and Zhao, the fresnel lens can be used as a concentrator in solar cookers[11][12]. To create a low-cost and simple solar cooker, we used a convex lens which cheaper and easier to find as a light concentrator.

The solar cooking device is a direct solar cooker with a rectangular shape. Box size and design not for a large scale cooking with dimensions 45 x 20 x 12 cm. The simple design and small size make this device can be carried and placed anywhere with much sunlight. The box was made from wood and a compound of three reflectors. The size of the reflective panel was customized with the size of a rectangular box, so it can be closed neatly. One panel used a 900 cm² area and the other two panels used a 418 cm² area. The reflector used a mirror and reflective film (Aluminum Tape) for a comparison. Inside the box, styrofoam is coated with a black tint attached to absorb more sun rays and prevent loss of heat.

3. Experimental Set up

The performance of solar cooker device was evaluated with various materials. Two identical pots were made of carbon steel with a non-stick coating. The diameter of the pot is 14 cm with 9 cm height. As shown in figure 2, two pots put together in the solar cooker to get two different data with and without a convex lens. The pot fills with 0.5 l water (499 gr) and is heated simultaneously. A convex lens with a 50 mm focus was put directly on top of one pot.



Figure 2. Solar cooker box type with Aluminum Tape reflector

Investigation performance of solar cooker box takes a place in a back yard with limitations of sun rays. A box with a mirror reflector was used to boil two pots of water with one of them added a convex lens on top. The two pots were heated and investigated simultaneously to compare directly the performance of the convex lens. The mirror reflector is then closed and coated with a reflective mirror from aluminum tape. With the same treatment as the mirror panel, the solar cooker performance has been investigated.



Figure 3. Solar cooker box type with mirror reflector in a back yard.

The instrument used to collect data in this research was Solar meter, Lux meter and Gun thermometer. A Solar meter is a tool to measure solar power radiation in W/m². Lux meter is a tool to know the amount of illuminance light per square meter in lux and a Gun Thermometer to gauge the temperature

of water in Celcius. Water temperature solar power radiation and lux meter checks and noted regularly every 5 minutes. All the data take manually without any sensor or automatic machine.



Figure 4. Instrument used to measurement solar power radiation (a) Solar power meter, Illumination (b) Lux meter and temperature (c) infrared thermometer gun

4. Result and discussion

Performance solar cooker box type with mirror reflector has been investigated and showed in figure 5. The test result with a mirror reflector showed that the maximum temperature reaches 63°C mark at 80 minutes. The test takes time from 1.00 pm to 2.20 pm because when the time reaches 14.30 the air ambient became different from the change of sun direction. Meanwhile, the test result from the aluminum tape reflector in figure 6 showed the maximum temperature reaches 64°C at 80 minutes. From the result, we can conclude that the performance of the mirror reflector and aluminum reflector didn't show much difference. Therefore, we can replace the mirror reflector which much heavier and more expensive with lighter and cheaper aluminum tape.

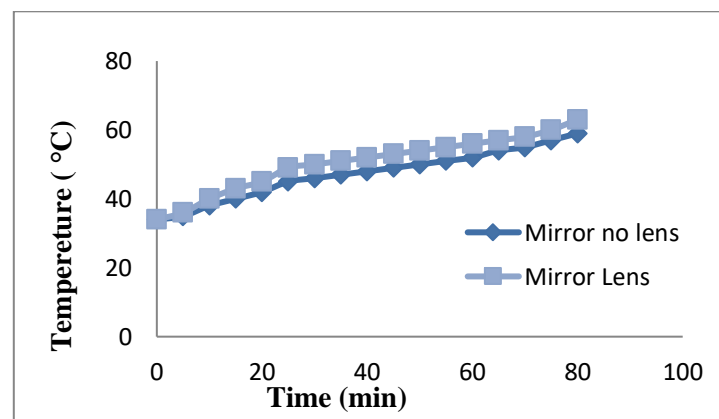


Figure 5. perform of solar cooker box type with mirror reflector

The Performance of the convex lens can be shown in figures 5 and 6. With a mirror reflector, maximum temperature with a convex lens reaches 63°C and 59°C without a convex lens. From an aluminum tape reflector, the maximum temperature reaches 64°C with a convex lens and 60°C without the lens. It showed that a convex lens can enhance the performance of solar cookers with an average 4°C. as expected, the result showed a pot with a convex lens get higher temperatures than a pot without a lens. A convex lens is employed as a shaping lens to focus a group of sun rays so that the light can be more focused and many get through to a pot[13]. However, better performance can be achieved if we adjust the convex lens with a better high and incline[14]. This result still far enough from fresnel lens used as a concentrator in a solar cooker. According to[6][12], the solar cooker with fresnel performance

twice to third times higher the temperature than the parabolic solar cooker. It is because the fresnel lens replaces the parabolic as a concentrator and used the size as big as a parabolic concentrator in solar cooker. Therefore, in this study we still used mirrors or aluminum tape as panel reflectors and added a convex lens with 5 cm diameter as a light collector before sunray reach the pot. Thus from the size and the used in this research, the convex lens cannot reach high performance, unlike the fresnel lens.

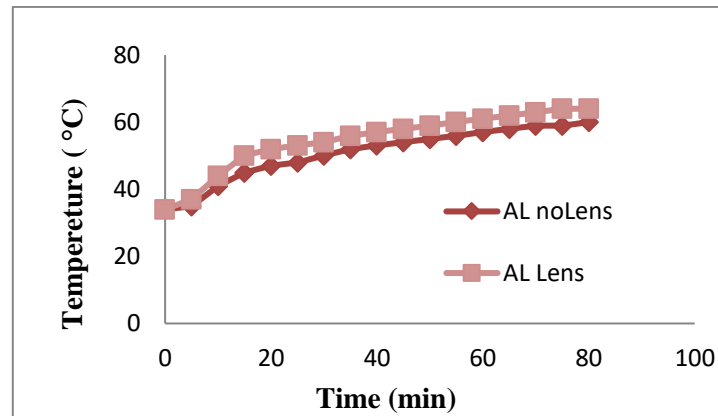


Figure 6. perform of solar cooker box type with Aluminum Tape reflector

The use of a heat absorber in a solar cooker as important as another component, table 1 figured temperature from the solar cooker when there are only isolated tape to prevent heat loss and adding styrofoam with black paint as a heat absorber. With the same aluminum tape as panel reflector, performance of solar cookers with styrofoam as heat absorbers has been measured. When the device is only coated with black isolated tape, the highest temperature with lens reaches 64°C. Meanwhile, solar cooker with black styrofoam, the highest temperature with lens reach 73°C it is 9°C higher than black isolated tape.

Table 1. Analysis of different heat absorber in solar cookers

Time (Minutes)	Isolated		Solar Radiation (W/m²)	Lux Meter	Black		Solar Radiation (W/m²)	Lux Meter
	Tape				Stryroform			
	No Lens	With Lens			No Lens	With Lens		
0	34	34	1173	110	34	34	1096,6	149,1
10	41	44	1095,3	131	42,5	44	1258,6	146,7
20	47	52	1168,2	135,6	50	52	1074	143,4
30	50	54	570	101	53	57	203,3	28,6
40	53	58	1209,4	118	55	59	1187,8	145,3
50	55	59	524	107	58	60	272	33,1
60	56	60	1157	126	59	62	1193,3	126,7
70	57	61	443,6	106	61	64	1160,4	121,4
80	59	63	1079	129	65	68	1240	151,3
90	60	64	1150,3	135	69	73	1186,2	130,3

Overall, the performance of solar cooker box typer in this research has been done successfully. With the purpose of sterilizing water for drinking purposes, we already reach a maximum temperature of 73°C which is considered can eliminate bacteria in water[15]. Performance comparison from another solar oven has been reported, to reach temperatures higher than 60°C needs time longer than 5 h[16]. It is a lot slower, considered the solar cooker box in this experiment can reach 64°C within 80 minutes. The solar power radiation, illumination and temperature of air ambient was another factor to help the water

in solar cooker device can reach a high temperature. However this result still far from a common solar cooker with a parabolic trough[17]. Therefore further study with a different type and bigger size of the convex line, incline and advance type solar cooker highly recommend for pursuing a better result in solar cooker performance.

5. Conclusion

The performance of solar cooker box type has been investigated. The result showed that temperature performance with a reflector from a mirror has a similarity with a reflector from aluminum tape. Therefore author suggests using aluminum tape caused it has a lighter weight which can move easily and lower prices to realization the low-cost prototype of solar cookers. An addition of a convex lens is used to enhance the temperature of solar cooking. It showed that a convex lens can enhance the performance of solar cookers with an average 4°C. It is because the characteristic of the convex lens can collect the beam so that the light can be more focused and many get through to a pot. Addition of styrofoam as a heat absorber help to enhance higher temperature until 9°C. Overall, the solar cooker box type in this research showed a good performance thus it can be used for sterilization of drinking water. Further study with a different type and bigger size of a convex lens, incline and advance type solar cooker highly recommend pursuing a better result in a solar cooker.

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