Solar Cooker Report

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FAQs - Solar Cooking

Q) What all can be cooked using Box Solar Cooking

Solar cooking is best when it comes to cooking food which involves the uniform distribution of heat through a medium such as water. Eg Rice, Noodles, Dal, Boiling of Egg, Vegetable soup. Since it offers a relatively lower temperature it can easily cook without burning the food.

Q) What all cannot be cooked using Box Solar Cooking

Solar cooking has a relatively low temperature so it cannot be used for cooking that involves higher temperatures > 100℃ as sufficient temperature cannot be reached, Eg) Baking Cookies, Cakes, Deep frying with oil, Popcorn. Since the box is closed we cannot cook food that requires continuous stirring and sauteing.

Q) How is the taste of the food compared to cooking on the fuel.

The taste is nearly the same. Both types of food taste well. But in our opinion, The solar cooked noodles had uniformly soaked the water and had a better texture than gas cooked ones but the noodles masala hadn't mixed completely due to the absence of stirring. Otherwise, the taste was nearly the same.

Q) Can we use this for a community kitchen for about 200 inmates?

Yes, It would be practically more feasible than a parabolic one since the person cooking could cook all the dishes at once for a box-type cooker. The box can be made sufficiently large to accommodate 4-5 utensils and such a box can be given to each family of 5 ~40 boxes. It can be used for a community kitchen but it is still doubtful whether the community would prefer solar cooking over wood chulha/gas.

Q) How do various types of solar cookers vary?

Box Type Solar Cooker	Parabolic Reflector Cooker
• Reaches Lower Temperatures and takes more time to cook • Allows more dishes to be cooked at the same time. • Allows more equitable and uniform distribution of heat • Uses plane mirrors which are easier to procure and work with	• Reaches Higher Temperatures and lesser time to cook • Allows only one dish to be cooked at a time • Allows focused distribution of heat only along the bottom of the dish • Relatively difficult to construct and it is relatively difficult to obtain a perfect parabolic surface or mirror

Q) Conventional Gas Cooking vs Solar Cooking?

Solar Cooker	Gas Cooking
• Has a very less energy footprint and carbon footprint since directly doesn't produce CO2 emissions • Inexpensive compared to Gas cooking • Heavily dependent on the sunlight and weather and time. Can be only operated efficiently in sunny weather and during afternoons	• Produces CO2 emission as involves combustion of LPG gas. • Relatively more expensive than Solar Cooking • Independent of weather and time can be cooked in any season and anytime can be also be cooked at night or in winters

Rohan - Experiences

In my opinion, it was a really amazing experience, I had never experienced a practical project. In our high school, we were only supposed to focus on the theoretical aspect of the subject. Here everything from ideation, implementation and procurement of all the materials required had to be done by us. We had to go to the mirror stores and hardware stores to get things (which I had never experienced before in a project) like the mirror and hinge. Also the satisfaction we get after cooking a meal using the device made by us, is unsurpassable! Also, I got a chance to integrate my favourite topics like computer programming and microcontroller programming with Solar Cooking to calculate the parameters of the cooker. I'm really grateful to have participated in a project such as this!

Aabir - Experiences

This was my first opportunity to test a theoretical knowledge through applying it to make a daily life, functioning model to work and stand by the principles used to plan the project. This was the first time I faced the problems of making a working prototype of a plan like arranging materials, durability, efficiency, cost, etc which are not thought through during the conceptual planning of a project. It was a massively successful project and it gave me a lot of motivation to take more such activities up when I saw my cooker was reaching temperatures close to 100℃. Overall it was a great learning opportunity with tons of first hand experience which lacks in these online semesters and I look forward to more such opportunities.

Our Learnings

1) Theoretically designing and implementing practically it are two completely different things.

2) Importance of teamwork and coordination in the successful completion of a team project.

3) How to improvise, if a certain plan fails then trying to solve or to address that issue.

4) How to calculate parameters like F1 using temperature data and other parameters

5) Most importantly learned how much fun Solar Cooking is!

Work allotment in the team

1) Both members had to individually make their own solar box type cookers. Both of us had to individually procure the raw materials.

2) Additionally, the contents of the report were decided with mutual agreement. The contents were filled together via online file sharing.

3) Both of us met at a common location in Bangalore on two different days and performed the temperature recording experiment together and plotted the graphs, did the F1 calculations together.

4) The cooking of food and tasting the food .etc was done at our individual homes.

Plan of Action

The design details were conceived by both of us during a brainstorming session held where both of us put forward points while the other would either support or try to counter various claims in a formal argument. The final design parameters chosen with mutual agreement were

1) Box type solar cooker with reflecting plane mirrors

Pros

- Relatively easier to construct and higher feasibility than parabolic type, with household materials
- Allowed multiple dishes to be cooked at once due to equitable distribution of heat inside box chamber unlike focused at a point in spherical
- Plane mirrors are more easier to work with than spherical mirrors

Cons

- Takes more time and reaches lower temperatures than a parabolic type solar cooker

2) Adjustable freely rotatable lid with reflector

Pros

- Allowed more sun rays to enter the cooker through the optical phenomenon called reflection

3) Box sourced from Cardboard

Pros

- Cheaper and more easily procurable from household items.
- Cardboard has good heat-insulating properties.

4) A fixed hinge type mechanism in order to keep the angle fixed

Pros

- Allowed us to freely rotate and adjust the reflector in any given direction to allow maximum light entry into the box
- Serves as a protection for the reflecting mirror in times of heavy winds.

5) Usage of transparent glass middle lid so as to account for greenhouse effect to avoid radiant heat losses

Pros

- Improving the heating property of the cooker by avoiding air circulation.
- Accounting for greenhouse effect to avoid radiant heat losses, as glass avoids infrared radiation from leaving the box.

6) Usage of insulating material (like bubble-wrap,cardboard planks, newspaper) in between the inner utensil and box

Pros

- To avoid heat loss by conduction and to improve the insulating properties of the cooker to increase efficiency.

7) Blackening of the outermost layer of insulation and also blackening of the steel utensil used from the outside.

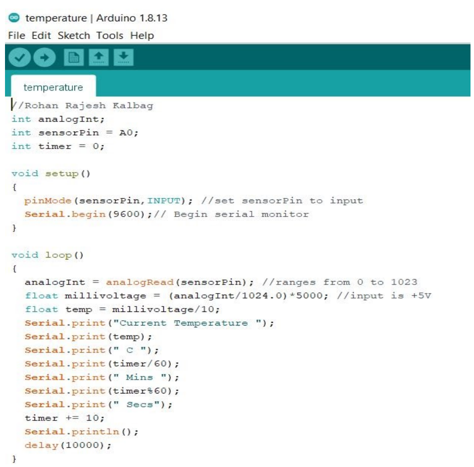
Pros

- Black surfaces are very good absorbers of heat and can absorb a wide range of wavelengths of light.

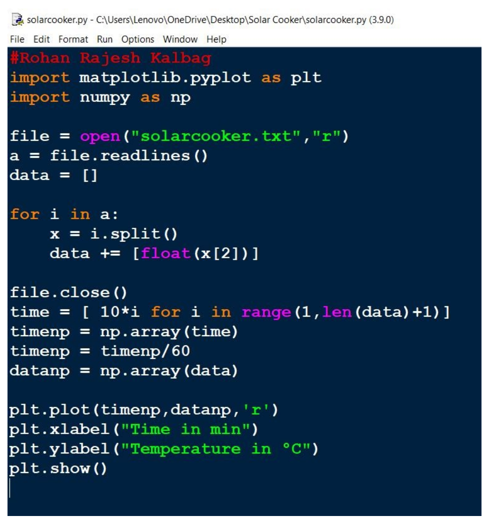
Parameters Monitored

Additionally, we decided that the parameters that we will be measuring the design parameters of the box such as **length** and **area** using a meter scale with a least count of 1mm. And also using an **Arduino UNO** microcontroller board we programmed the **LM 35 temperature sensor** to print out a text file with the temperature data as a function of time and also we used **Matplotlib.pyplot** library of **Python 3.9** to plot the data to give a temperature vs time graph.

We used the **temperature**, **length** and **area** parameter readings to estimate the value of **F1** or the **First Figure of Merit** of the cooker, which gave us an idea of the efficiency of the solar cooker.

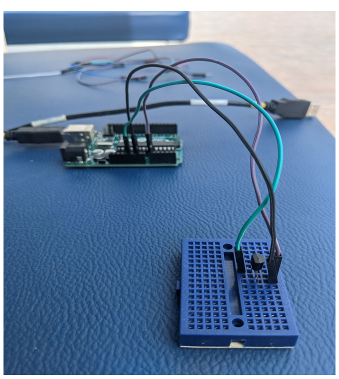

temperature | Arduino 1.8.13
File Edit Sketch Tools Help
temperature

```
//Rohan Rajesh Kalbag
int analogInt;
int sensorPin = A0;
int timer = 0;

void setup()
{
  pinMode(sensorPin,INPUT); //set sensorPin to input
  Serial.begin(9600);// Begin serial monitor
}

void loop()
{
  analogInt = analogRead(sensorPin); //ranges from 0 to 1023
  float millivoltage = (analogInt/1024.0)*5000; //input is +5V
  float temp = millivoltage/10;
  Serial.print("Current Temperature ");
  Serial.print(temp);
  Serial.print(" C ");
  Serial.print(timer/60);
  Serial.print(" Mins ");
  Serial.print(timer%60);
  Serial.print(" Secs");
  timer += 10;
  Serial.println();
  delay(10000);
}
```


solarcooker.py - C:\Users\Lenovo\OneDrive\Desktop\Solar Cooker\solarcooker.py (3.9.0)
File Edit Format Run Options Window Help

```
#Rohan Rajesh Kalbag
import matplotlib.pyplot as plt
import numpy as np

file = open("solarcooker.txt","r")
a = file.readlines()
data = []

for i in a:
    x = i.split()
    data += [float(x[2])]

file.close()
time = [ 10*i for i in range(1,len(data)+1)]
timenp = np.array(time)
timenp = timenp/60
datanp = np.array(data)

plt.plot(timenp,datanp,'r')
plt.xlabel("Time in min")
plt.ylabel("Temperature in °C")
plt.show()
```

Above - codes written to implement the temperature sensor



Above - pictures of the sensor and of the experiment performed on both cookers

Parameters

Aabir - Design Parameters

- Box-Type Cooker
- Outer Length of box = 44 cm
- Outer Breadth of box = 36 cm
- Outer Height of box = 18 cm
- Weight of box = 3.2 kg
- Dimensions of glass lid = 44 x 36 cm
- Dimensions of mirror = 44 x 36 cm
- Dimensions of inner cavity of box to hold utensil = 34 cm x 30 cm x 16cm
- The average diameter of nearly cylindrical utensil = 14 cm
- Height of cylindrical utensil = 6 cm

Aabir - Performance Parameters

- First Figure of merit F1 = **0.0157** Km^2/W
- Upfront cost = ~ **₹300-400**

Rohan - Design Parameters

- Box-Type Cooker
- Outer Length of box = 33cm
- Outer Breadth of box = 20 cm
- Outer Height of box = 11cm
- Weight of box = 3.6 kg
- Dimensions of glass lid = 33 x 20 cm
- Dimensions of inner cavity of box to hold utensil = 26cm x 17cm x 11cm
- Area of upper reflecting mirror = 26cm x 17cm
- Average diameter of nearly cylindrical utensil = (7.5+11)/2 =9.25 cm
- Height of cylindrical utensil = 6cm

Rohan - Performance Parameters

- First Figure of merit F1 = **0.0174** Km^2/W
- Upfront cost = ~ **₹300-400**

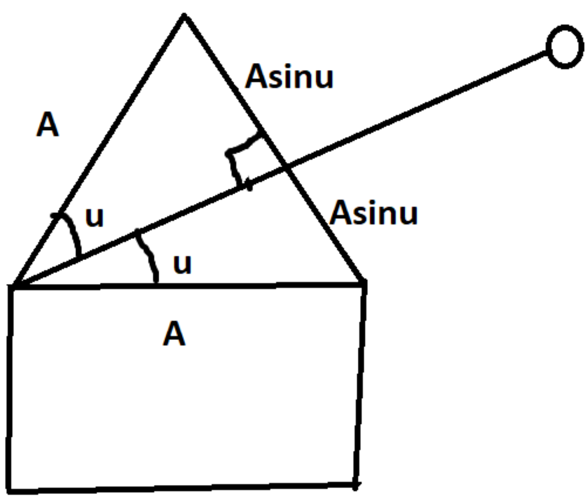
Rohan - Calculation of First Figure of Merit

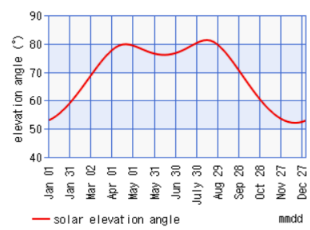
1) Water was taken as load in the solar cooker and allowed to heat in solar cooker under afternoon sun until a steady temperature T_{pot} was reached

2) T_{pot} was reached in around 30 mins, the value of T_{pot} was measured as **~85°C** from the temperature plot which was obtained from the readings of LM 35 sensor with Arduino UNO board

3) The mirror was aligned in such a way that maximum light was reflected onto the cooker, by geometry was 2u, where u is the average angle made by the sun with the x-axis

4) Average angle made by the sun with respect to the x-axis = **~75**° at 1 pm for (It was done on Mar 25)
(According to the data provided by https://keisan.casio.com/exec/system/1224682331)





Date	Elevation angle	Azimuth angle
Jan 01	52.92	194.08
Jan 06	53.56	193.46
Jan 11	54.35	192.95
Jan 16	55.31	192.58
Jan 21	56.41	192.36
Jan 26	57.64	192.33
Jan 31	58.99	192.50
Feb 05	60.45	192.90
Feb 10	62	193.55
Feb 15	63.62	194.49
Feb 20	65.3	195.77
Feb 25	67.01	197.44
Mar 02	68.73	199.58
Mar 07	70.44	202.26
Mar 12	72.11	205.58
Mar 17	73.72	209.67
Mar 22	75.22	214.67
Mar 27	76.57	220.73
Apr 01	77.73	227.92
Apr 06	78.67	236.26

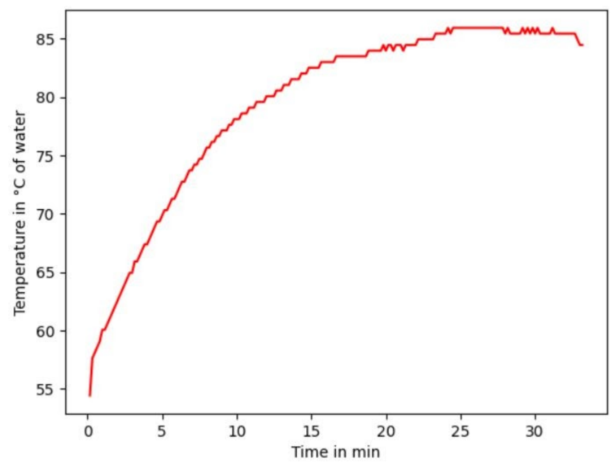
Above - pictures of the geometric symmetry assumed by us to evaluate the projected aperture area and elevation angle of the sun data

5) Projected Area with respect to the sun is $2Asin(u)$

6) Average area of aperture = $2Asin(75°)$ = 2x26x17x0.96 = **848.64** cm^2

7) Average surface area of cylindrical utensil = $\pi r^2 + 2\pi rh$
= 3.14((4.625)x(4.625) + 2 x 4.625 x 6) = **241.43** cm^2

8) Temperature of surroundings = **36°C**



(Above is the plot obtained by using Matplotlib library of python on the data acquired from the LM35 sensor with Arduino for Rohan)

9) T_{pot} = **85°C** T_{amb} = **36°C**

10) C (concentration factor) = Area of aperture / Area of pot = 848.64/241.43 = 3.51. Average Intensity (I_o) of Sunlight in India at afternoon = 800 W/m^2

$$F1 = (T_{pot} - T_{amb})/(C \times I_o)$$

11) **F1** = (85-36)/800*3.51 = **0.0174** Km^2/W

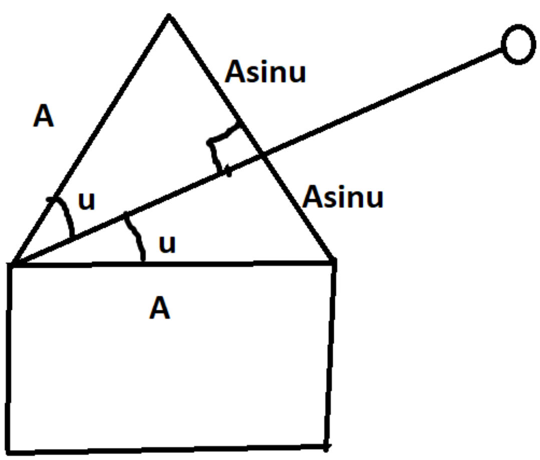
Aabir - Calculation of First Figure of Merit

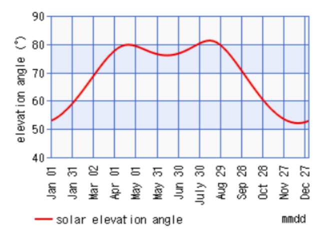
12) Water was taken as load in the solar cooker and allowed to heat in solar cooker under afternoon sun until a steady temperature T_{pot} was reached

13) T_{pot} was reached in around 35 mins, the value of T_{pot} was measured as **~98°C** from the temperature plot which was obtained from the readings of LM 35 sensor with Arduino UNO board

14) The mirror was aligned in such a way that maximum light was reflected onto the cooker, by geometry was 2u, where u is the average angle made by the sun with the x-axis

15) Average angle made by the sun with respect to the x-axis = **~77**° at 1 pm (It was done on Apr 3)
(According to the data provided by https://keisan.casio.com/exec/system/1224682331)





Date	Elevation angle	Azimuth angle
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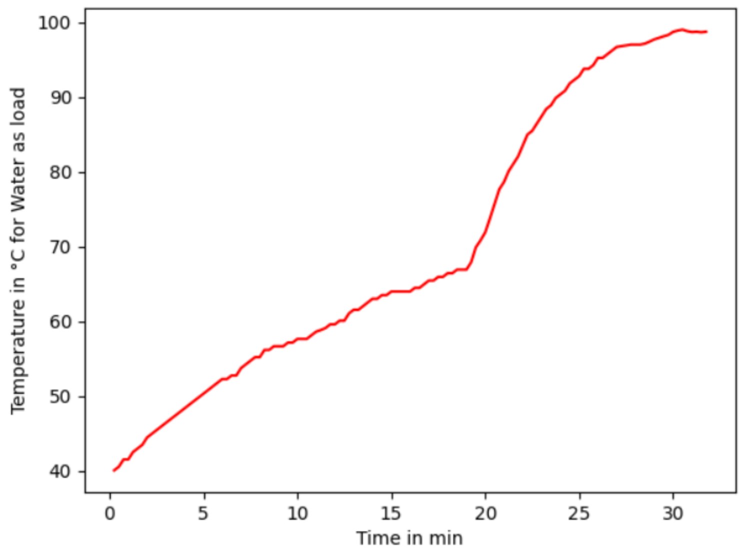
Above - pictures of the geometric symmetry assumed by us to evaluate the projected aperture area and elevation angle of the sun data

16) Projected Area with respect to the sun is $2Asin(u)$
17) Average area of aperture = $2Asin(77°)$ = 2x34x30x0.97 = **1987.7** cm^2
18) Average surface area of cylindrical utensil = $\pi r^2 + 2\pi rh$
= 3.14(49 + 2 x 7 x 6) = **417.62** cm^2
19) Temperature of surroundings = **38°C**



(Above is the plot obtained by using Matplotlib library of python on the data acquired from the LM35 sensor with Arduino for Aabir)

20) T_{pot} = **98°C** T_{amb} = **38°C**

21) C (concentration factor) = Area of aperture / Area of pot = 1987.7/417.62 = **4.75**

22) Average Intensity (I_o) of Sunlight in India at afternoon = 800 W/m^2

$$F1 = (T_{pot} - T_{amb})/(C \times I_o)$$

23) **F1** = (98-38)/800*4.75 = **0.0157** Km^2/W

Comparison of Results and Inference

Both cookers made by us were of box type and followed similar design parameters, it was observed that Food was cooked in nearly the same amount of time for both of us.

Instant noodles (Maggi) was cooked in nearly **30-35 min** for both of us. **Rice** on the other hand took nearly **1 hr 30 min - 2 hrs** to cook.

The temperature vs time plot was observed as a sharply increasing and then saturating curve. The temperature where it saturated was the steady-state temperature of the solar cookers.

However in the case of Aabir's graph at nearly ~20 minutes a sharp point of not differentiability is seen, we believe this was because the cooker was moved toward a more sunny point due to the box being obstructed by the shade of a nearby tree.

It was observed that for both of us the F1 or the first figure of merit was nearly the same, and of the same order. $F1_{Aabir} =$ **0.0157** and $F1_{Rohan} =$ **0.0174.**

A small difference was seen of 0.0016 between the first figures of merit of our cookers. This is because of the difference in C and $T_{pot} - T_{amb}$ values for both our cookers. This may have arisen because our cookers were of different dimensions and had different type of insulation (bubble wrap and newspaper for Aabir), (cardboard planks and bubble wrap for Rohan)

Because of which $(T_{pot} - T_{amb})/C$ ratio was relatively more for Rohan than Aabir. We believe this is the reason for the difference in the values of F1 for both the cookers.

Annexures

Acknowledgements

1) **Professor S.B Kedare**, Instructor for EN 110, for giving us this opportunity and supporting us by introducing the topic of solar cooking in lectures, answering various doubts, queries and providing various sources of reading material.

2) **Aryan** and **Varad**, TAs for EN 110, for clarifying doubts and queries regarding this project.

3) https://keisan.casio.com/exec/system/1224682331
4) https://en.wikipedia.org/wiki/Solar_irradiance
5) https://create.arduino.cc/projecthub/infoelectorials/project-003-arduino-lm35-temperature-sensor-project-0a43ba
6) https://kredlinfo.in/Solaroffgrid/SOG%20Website/Solar%20Thermal/solarcooking.pdf
7) https://www.solarcookers.org/files/1314/2427/8672/THERMAL_TEST_PROCEDURE_FOR_BOX-TYPE_SOLAR_cookers.pdf

Some Photos of Testing and the Cooked Food

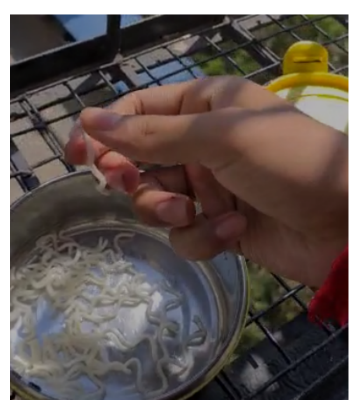










Thank You!