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THERMAL PERFORMANCE OF TRAPEZOIDAL SOLAR COOKER

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ABSTRACT

Energy is an important source for all sectors of any country's economy. It is a major input for socioeconomic development and poverty eradication. The standard of living of any country is mostly dependent on per capita energy consumption. Due to rapid deterioration in the supply of fossil fuels, the solar energy can be the most appropriate option compared to other alternative energy resources. In rural areas almost 75% of the energy is used for cooking purpose. The solar cookers have a relevant place in the present fuel consumption pattern. But the position of the sun varies continuously throughout the daytime which affects the absorption rate. An advance design is to be proposed for the maximum utilization of solar radiation concentrated over solar cooker. In the proposed trapezoidal solar cooker the shape will be such that the solar radiation incident upon the surface gets concentrated towards the Centre of the cooker. From above description the objective of present work is to study the effect of angle of inclination on the thermal performance of trapezoidal of solar cooker.

Introduction

The energy availability plays a vital role in economic activity because production and manufacturing can be fulfilled by energy consumption only. Nowadays low cost energy is necessary for economical development of any country but because still the major energy extraction is possible using fossil fuels and those countries which have not sufficient amount of such fossil fuel facing lot many issues related unemployment; but the solution of this energy crisis is available from alternative energy sources like solar energy, wind energy and bio mass and bio fuel etc.

Solar Cooker

The evolution for the need of renewable energy resources is rising these days. Also the availability of conventional resources is drying up. The idea of utilizing renewable energy in our day to day life is popular now. In a tropical country like India there is sunshine for nearly 9 months in a year. This kindled the idea, that if a cost efficient solar cooker is used in a house for most of the domestic purposes, replacing gas-stoves, it not only benefits the household but also reduces the cooking fuel demand.

Solar cooker is a device that cooks food using only sun energy in the form of solar radiation. The solar cooking saves a significant amount of conventional fuels. The solar cooking is the simplest, safest, clean, environment friendly, and most convenient way to cook food without consuming fuels or heating up the kitchen.

A major concern of today is the rapidly depleting natural resources. So it is the urgent need of time to reduce the dependency on non-renewable sources, judiciously using the remaining sources and at the same time switching to new and better alternatives and renewable source of energy. In most parts of India, solar energy is available almost throughout the year and can be used as alternate input to meet out energy needs. Solar used for various domestic and agricultural requirements including cooking, drying, dehydration, heating, cooling and solar power generation. Solar cookers have a long history dating back almost 18th century when Nicholas-de-Saussure built first ever Solar Box Cooker. Today there are about 60 major designs and more than 100 of however the solar cooking has not caught the imagination of peoples, except in places where shortage of conventional fuel like fire wood and the Solar cookers have attracted the attention of many researchers so far. Different types of solar cookers have been developed and tested all over the world. Today, there is challenge to manufacturing and evaluation of efficient and cheap solar cookers. There has been a considerable interest recently in the design, development and testing of various types of solar cookers.

Types of Solar Cooker

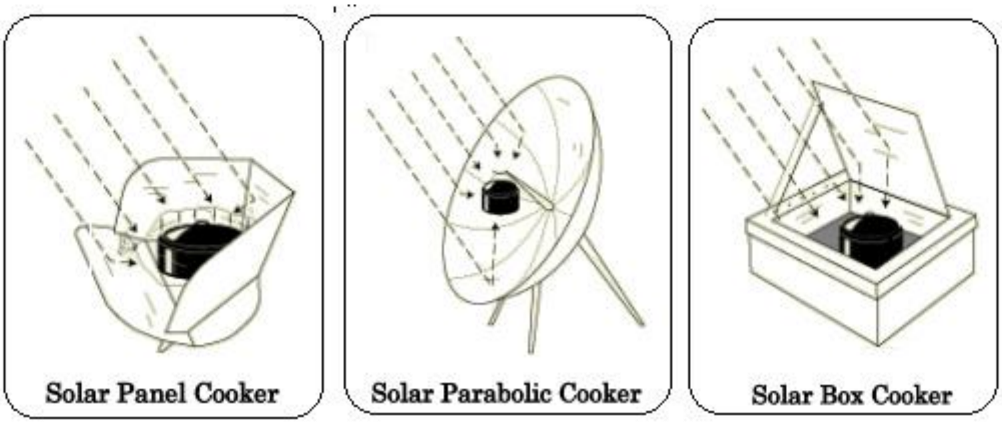


Fig. Types of Solar Cookers

A. Box Cookers

Box cookers are the most common type made for personal use. They consist of an enclosed inner box covered with clear glass or plastic, a reflector, and insulation. There is a wide variety of patterns and plans that can be adapted to work with available materials. While they do not heat quickly, they provide slow, even cooking. Box cookers are very easy and safe to use, and fairly easy to construct.

B. Panel Cookers

Panel cookers are flat reflective panels which focus the sunlight on a cooking vessel without the inner box common in box cookers. Panel cookers are the easiest and least costly to make, requiring just four reflective panels and a cooking vessel, but they are unstable in high winds and do not retain as much heat when the sun is hidden behind clouds.

C. Parabolic Cookers

Parabolic cookers reach higher temperatures and cook more quickly than solar box cookers, but are harder to make and use. Parabolic cookers require more precision to focus the sunlight on the cooking vessel. If the sunlight is not focused exactly on the cooking vessel, the food will not cook. When the parabolic oven is used, the temperature must be watched so the vessel does not overheat, burning the food. The risk of burns and eye injury is greater with homemade parabolic designs. While they provide excellent results when used correctly, they are not easy to build at home and require great care to use.

1.5 Need of Solar Cooker

The Solar cookers are needed due to

1. High cost or Unavailability of commercial fuels – Kerosene, Coal, cooking gas and Electricity.

2. Deforestation caused by increasing firewood consumption.

3. Use of dung and agricultural waste as fuels instead of for soil enrichment.

4. Diversion of human resources for fuel collection.

Feasible Applications of Solar Box Cooker

The cooker is used to prepare simple cakes, roast cashew nuts, dry grapes, etc. It is an ideal device for domestic cooking during most of the year except the monsoon season and cloudy days. The cooking takes place at relatively low temperature, thus cooking is very similar to that of microwave cooking. The cooked items are very tastier, healthier and with all natural minerals, vitamins and proteins. It however cannot be used for frying or Chapatti making.

Literature Review

In the present chapter the contribution of different researchers are included which will be helped to decide dimensions and instrument of experimental set up.

C Z M Kimambo (2007) has studied a comprehensive study involving theoretical review, development work, experimental testing and evaluation of solar cookers was conducted for several years on six different types of solar cookers. The cookers are the ‘Sun Stove’ box cooker, wooden box cooker, panel cooker, reflector cooker with unpolished aluminum reflectors, reflector cooker with polished aluminum reflectors and reflector cooker with glass mirror reflectors. Results obtained indicate that many of the cookers could be used to cook food for households in areas with medium and high insolation, with appropriate selection of the type and specification of the cookers. The specification should be based on the measured insolation data of the location indication of the direct and diffuse components.

Table 2.1: Advantages and disadvantages of different solar cooker testing standards

Test standard	*Advantages*	*Disadvantages*
American Society of Agricultural Engineers Standard (Funk, 2000)	Simple Applicable in less developed areas	Analysis of performance of a cooker, rather than simply comparison is very difficult Does not address qualitative factors e.g. ease of use, safety, or financial issues
Bureau of Indian Standards Testing Method (Mullick et al, 1987)	Presented in a more technical framework than ASAE S580 Independent of weather conditions (such as wind speed, insolation, etc.)	Does not address qualitative factors e.g. ease of use, safety, or financial issues
European Committee on Solar Cooking Research (ECSCR) Testing Standard	Includes an exhaustive thermal testing regime Cheaper and easier to run – tracking pyranometer not required Explores qualitative factors e.g. safety, ease of cooking, pot access, durability etc. Useful for comparison of any cookers	Relies on measurements of time taken for certain conditions to occur Not well suited to multiple testing – procedure is quite comprehensive Requires long time – time taken for the basic test alone is 3 clear days

Table 2.2: Specifications of cookers tested

Type of cooker	*Glazing*	*Reflector*	*No. of pots*	*Nominal vol. (l)*	*Aperture area (m^2)*	*Collector area (m^2)*
'Sunstove' box cooker	Single PVC	Aluminium	1	2	0.34	0.34
Wooden box cooker	Double glass	None	1	2	0.24	0.24
Panel cooker	Single glass	Glass mirror	1	2	0.56	0.14
Reflector cooker – unpolished aluminium	–	Unpolished aluminium	1	4	1.61	1.61
Reflector cooker – polished aluminium	–	Polished aluminium1	1	4	1.61	1.6
Reflector cooker – glass mirror	–	Glass mirror	1	4	2.15	2.15

RAJENDRA C. PATIL MAHESH M. RATHORE MANOJKUMAR CHOPRA (2012) discussed about the solar cooker with its principal, types and advantages and disadvantages.

Table 1.1 Cooking Energy Scenario in India

URBAN SECTOR	RURAL SECTOR
• LPG (47.96%)	• Firewood (64.10%)
• Firewood (22.74%)	• Other sources of biomass –crop residue (13.10%)
• Kerosene (19.16%)	• Cow-dung (12.80%)
• Other fuels(10.14)	• LPG (5.67%) is now Increasing in importance.

Ibrahim Ladan Mohammed (2013) studied a parabolic dish solar thermal cooker, PDSTC, was designed and constructed. The cooker was required to cook food equivalent of 12 kg of dry (uncooked) rice per day for relatively medium size family, with a designed efficiency of about 50%.

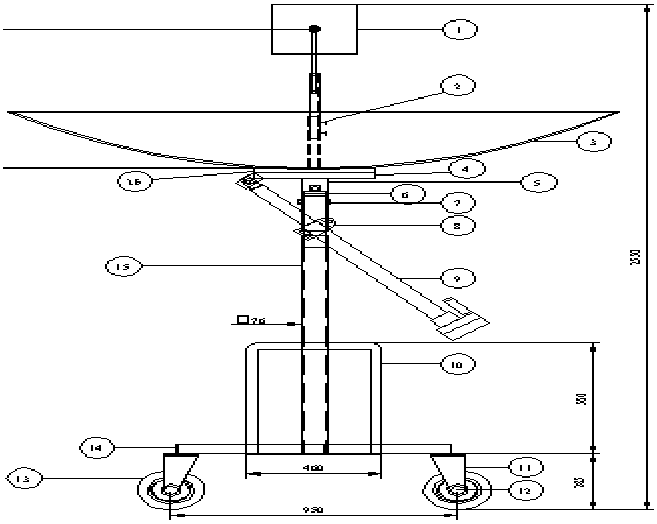


Figure 2.1 Assembled drawing of the PDSTC

Figure 2.2 Photograph of the PDSTC

The design and development of a parabolic dish solar thermal cooker for domestic cooking applications has been presented, together with the predicted and actual performance of the system. Although no detailed thermal performance analysis is presented, the cooking test results show that the cooker is always capable of cooking food equivalent of 3 kg of dry rice at a time, within the expected length of time and solar radiation levels. The total cooked food capacity of the cooker per cycle of cooking operation is about 9.7 kg, and the total per day is about 38.8 kg. The main research points of this paper are food-water volume and mass ratios.

Experimental Set up

In the present project work the Trapezium solar cooker will be made as first part of experiment. The both set up will be placed together and then in sunshine and observation will be noted using K type thermocouples to measure temperature.

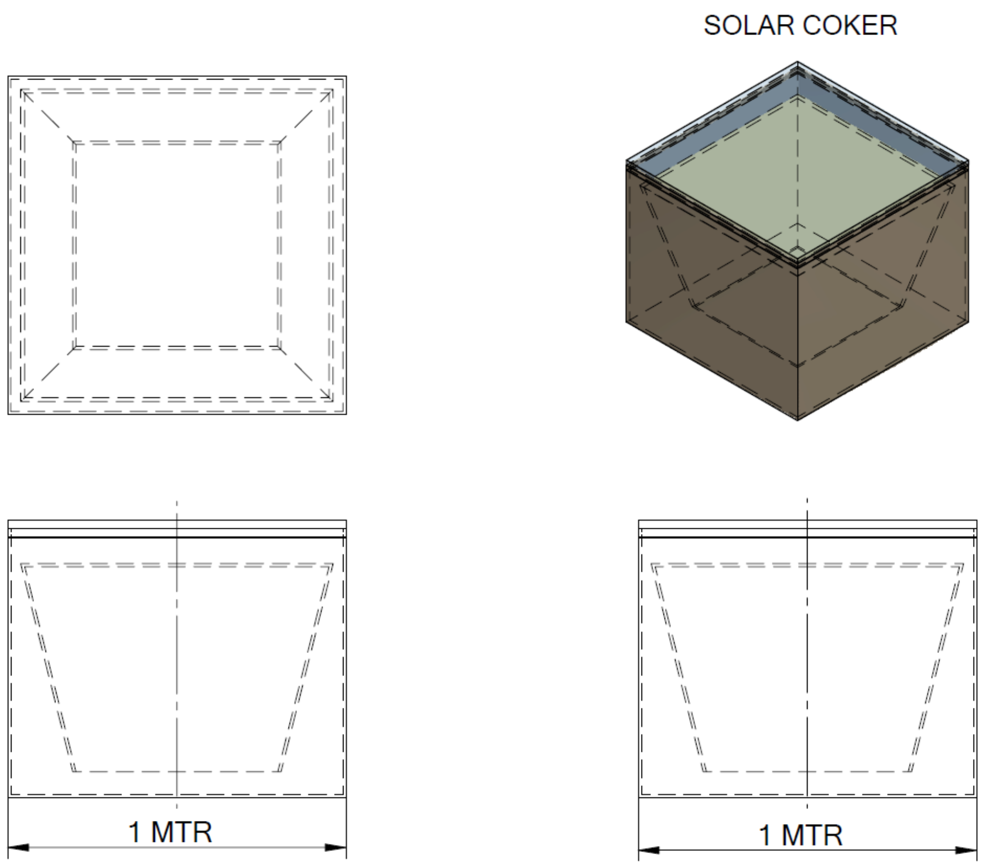


Fig 3.1 Proposed Experimental set

Constructional Detail

- **R** (Geometric concentration ratio), ratio between aperture area(collector) and absorber area(receiver):

$$R = \frac{Top\ Area}{Absorber\ area}$$

Case 1: **Rectangular** Design with square top:

$$R_1 = \frac{45.7^2}{45.7^2} = 1 = \mathbf{100}\%$$

Case 2: **Trapezoidal** Design with square top (Internal reflecting mirrors):

$$R_2 = \frac{45.7^2}{25.4^2} = 3.23 = \mathbf{323}\%$$

Difference:

$$R_2 - R_1 = 323 - 100 = \mathbf{223\%}$$

❖ **F (Effective volume factor) ($\frac{cm^2}{cm^3}$):**

$$F = \frac{Top\ Area}{Volume\ of\ cooking\ Chamber}$$

Volume of cooking Chamber= length × *breadth* × *height*

Case 1: **Rectangular** Design with square top:

$$F_1 = \frac{45.7^2}{45.7^2 \times 30.48} = \mathbf{0.032}\ \frac{cm^2}{cm^3}$$

Case 2: **Trapezoidal** Design with square top:

$$F_2 = \frac{45.7^2}{30.48 \times (45.7^2 + 25.4^2)/2} = \mathbf{0.050}\frac{cm^2}{cm^3}$$

Difference:

$$F_2 - F_1 = 0.050 - 0.032 = 0.018 = 1.8\%$$

Construction

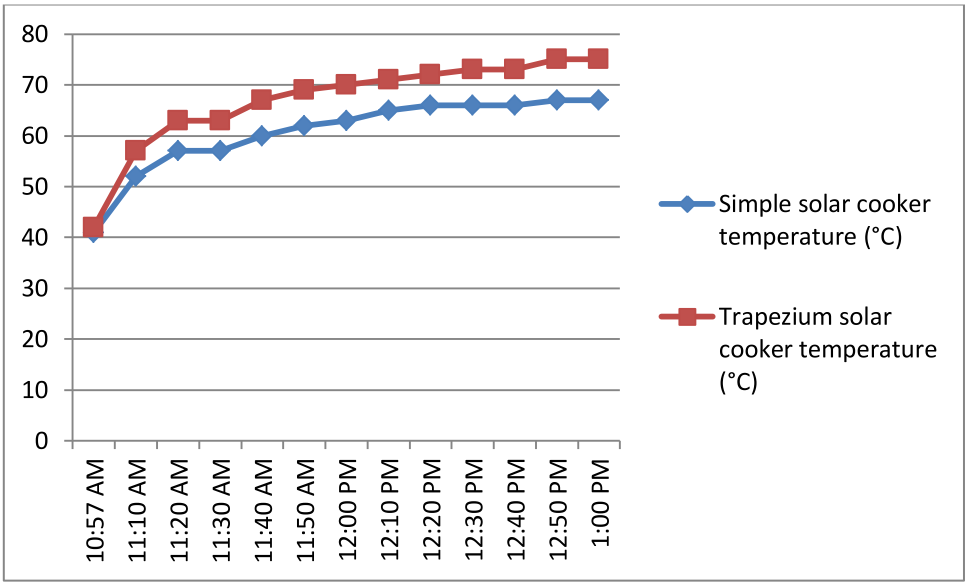
In the present work first of all 1 feet X 1 feet X 1.25 feet wooden box is prepared and then the mirror of trapezium shape with 1 feet height and 8 inch boom length and 12 inch upper length is pated in the box with silicon glue,

Fig Rectangular Model

Result and Discussion

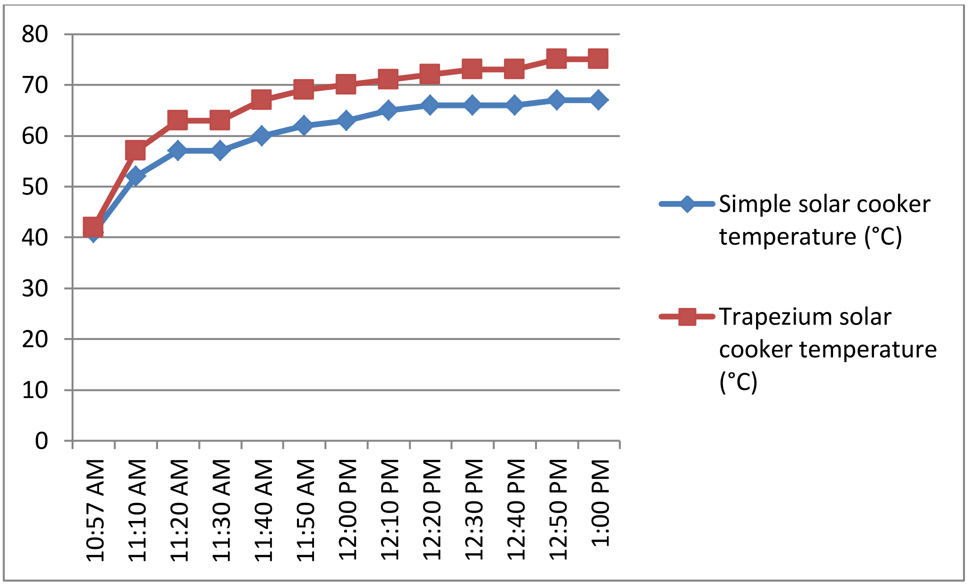
Case 1: Box readings

Sr. no	Time	Simple solar cooker temperature	Trapezium solar cooker temperature (°C)	Difference (°C)
1	10:45 AM	49	49	0
2	11:02 AM	60	66	6
3	11:12 AM	66	73	7
4	11:22 AM	70	79	9
5	11:32 AM	73	85	12
6	11:42 AM	74	89	15
7	11:52 AM	77	93	16
8	12:02 PM	78	96	18
9	12:12 PM	78	99	21
10	12:22 PM	79	104	25
11	12:32 PM	79	106	27
12	12:42 PM	80	107	27
13	12:52 PM	78	104	26
14	01:02 PM	81	105	24



Case 2: Simple vessel in both cookers with water

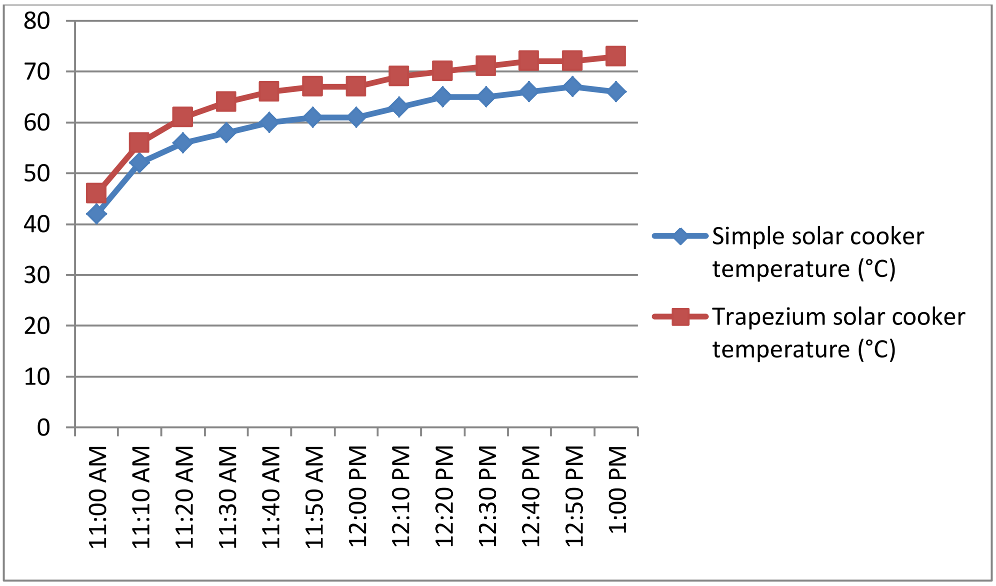
Sr. no	Time	Simple solar cooker temperature	Trapezium solar cooker temperature (°C)	Difference (°C)
1	10:57 AM	41	42	1
2	11:10 AM	52	57	5
3	11:20 AM	57	63	6
4	11:30 AM	57	63	6
5	11:40 AM	60	67	7
6	11:50 AM	62	69	7
7	12:00 PM	63	70	7
8	12:10 PM	65	71	6
9	12:20 PM	66	72	6
10	12:30 PM	66	73	7
11	12:40 PM	66	73	7
12	12:50 PM	67	75	8
13	01:00 PM	67	75	8



Case 3: Fin type vessel in both solar cookers

Water initial temperature: 38°C

Sr. no	Time	Simple solar cooker temperature	Trapezium solar cooker temperature (°C)	Difference (°C)
1	11:00 AM	42	46	4
2	11:10 AM	52	56	4
3	11:20 AM	56	61	5
4	11:30 AM	58	64	6
5	11:40 AM	60	66	6
6	11:50 AM	61	67	6
7	12:00 PM	61	67	6
8	12:10 PM	63	69	6
9	12:20 PM	65	70	5
10	12:30 PM	65	71	6
11	12:40 PM	66	72	6
12	12:50 PM	67	72	5
13	01:00 PM	66	73	7



From the above results it is quite clear that in case of trapezium solar cooker the results are better compare to conventional due to more black body radiation effect can be achieved in case of trapezium solar cooker also due to fin type vessel as surface area will increase which will increases the rate of heat transfer.

Conclusion

The major conclusion from the present work is with the proposed trapezium solar cooker with mirror as a reflecting medium better results can be obtained in terms of thermal performance of solar cooker.

Future Scope

By reducing weight of solar cooker using aluminum as reflecting material better results can be obtained.

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