DESIGNING AND TESTING THE EFFICIENCY OF BOX TYPE SOLAR COOKERS MADE FROM WOOD, ALUMINUM FOIL AND TRANSPARENT GLASS

MSc THESIS

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As Thesis Advisor, I here by certify that I have read and evaluated this Thesis prepared, under my guidance, by Sadinku Seyoum entitled**" Designing and Testing the Efficiency of Box Type Solar Cookers Made From Wood, Aluminum Foil and Transparent Glass".** I recommend that it be accepted as fulfilling the Thesis requirement.

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As Members of the Examining Board of the Final M.Sc Thesis Open Defense Examination, we certify that we have read and evaluated the Thesis prepared by Sadinku Seyoum and examined the candidate. We recommend that the Thesis be accepted as fulfilling the Thesis requirement for the Degree of Master of Science in physics (Environmental Physics).

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DEDICATION

This work is dedicated to **"GOD"** for he is always with me, especially when I was in my postgraduate study of six years, in every **"aspect".**

Thank you "GOD"

STATEMENT OF THE AUTHOR

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BIOGRAPHICAL SKETCH

The author was born in July, 1986 Wollega zone of Oromia Region. She attended her elementary primary school (starting from 1992) at Harato East Wollega zone of Oromia Region (from grade1-6) and at Harato (from grade 7-10) and Nekemte Comprehensive Secondary Schools (from11-12), respectively and compeleted her high school education in 2004. Thereafter she joined in Addis Ababa University and graduated with B.ED degree in physics on July 6, 2008. After she graduated she was employed in North shoa Zone Oromia Region as physics teacher at Garba Guracha preparatory and secondary school.Thereafter in 2011, she joined Haramaya University for her postgraduate study in physics.

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LIST OF ABBREVIATIONS

$BTSC_s$	Box-type solar cookers
$BTSC_1$	The first box type solar cooker
$BTSC_2$	The second box type solar cooker
$BTSC_3$	The third box type solar cooker

DESIGNING AND TESTING THE EFFICIENCY OF BOX TYPE SOLAR COOKERS MADE FROM WOOD, ALUMINUM FOIL AND TRANSPARENT GLASS

ABSTRACT

Three box type solar cookers were designed and prepared from locally available materials. Performance evaluations of the three box-type solar cookers were made by boiling water, heating sand and by measuring temperature of empty pots. The size of the boxes were 50 cm × 50 cm × 40 cm and 12 mm thickness. The absorber plate was made of 1 mm metal sheet and painted black. Commercially, available 4 mm thick transparent glass was used as cover material. The plane reflector was made of a commercially available aluminum foil which is sized to form a cover for the box when not being in use. The three boxes were identical except the first ($BTSC_1$) had only one glass cover, the second ($BTSC_2$) had double glass cover and the third (($BTSC_3$) double glass cover and reflectors. Three identical cooking pots were used for boiling water of 0.2 kg and heating sand of 1.3 kg. In all the three tests $BSTC_3$ outperformed the other two by a minimum 15^oC. The required time for heating water was reduced by using the reflector while steam condensation reduced by using the close-fitting pot.

Key words: Solar cooker, box-type solar cooker

1. INTRODUCTION

Solar energy has importance on energy and environment. As the world becomes more environmentally conscious, there is a rising deforestation and finding renewable energy options to fossil fuels is very essential. Currently, solar energy is meeting the vital energy requirements for a substantial percentage of the world's population particularly in developing countries. One of the essential energy needs for human living is for cooking (Soni and Chourasia, 2014).

Cooking is the most important energy consuming operation in the domestic sector. In India for example, more than 90 percent of the total house hold energy in rural areas is consumed in kitchen by burning approximately 133 million tons of firewood (Pohekar *et al*., 2003). The energy consumption for cooking constitutes half of India's total energy consumption and no other form of energy has greater impact on the environment or is more crucial for human survival.

Box type solar cooker, parabolic concentrator type and panel type solar cookers, are some of the representative models of solar cooking technologies which are being used worldwide. Out of the available models of solar cookers the box type solar cookers have the maximum attention because of their easy handling (Ashok, 1988). The instrument required for the testing of the solar cooker was described by Dubey (2001). Ekechukwun and Ugwonke (2003) explained the augmentation of the plane reflector used in the box type solar cooker. The construction details of the box type solar cooker are simple but scientific backup is needed for better performance in the field (Sharan and Mania, 2005).

Box-type solar cookers are suitable mainly for the boiling type of cooking. The cooking temperature in this case is close to 100°C. A large fraction of the mass of food products is due to water, and more water may be added in the boiling type of cooking. As a result, sensible heating up to the cooking temperature requires almost 4.2 kJ/kg°C (Soni and Chourasia, 2014).

Solar cooker is relatively pollution free although the cost of environmental pollution during manufacture and construction should not be neglected. But operation and maintenance costs are free since there are no moving parts. It is found in different versions (Daniel, 1990; Amer, 2003; Ekechukwun and Ugwonke*,* 2003;). The basic purpose of a solar box cooker is to heat things up, to cook food, purify water, and sterilize instruments.

A solar box cooks because the interior of the box is heated by the energy of the sun. Sunlight enters the solar box through the glass. It turns to heat energy when absorbed by the dark absorber plate and cooking pots. This heat input causes the temperature inside of the solar box cooker to rise until the heat loss of the cooker is equal to the solar heat gain. This way temperatures sufficient for cooking food and heating water are easily achieved (Yousif *et al*., 2012).

The addition of a plane reflector to a box-type solar cooker increases the obtained cooking temperature and thermal performances (Algifri and Al-Towaie, 2001). Box cookers do not have to be realigned with the position of the sun during the typical cooking time and do well with fluctuations in solar radiation. This makes them easier to use in everyday life (GTZ, 2007). The aim of this project is to test performances of three box type solar cookers, designed from locally available materials; wood, aluminum foil and transparent glass, at Kuyu District of North Shewa Zone of Oromia Regional State.

1.1. Statement of the Problem

In Ethiopia and many other developing countries commercial fuel like coal, kerosene, cooking gas and electricity are expensive beyond the economic capacity of many people. Majority of the people depend on fuel wood and that has led to fast and rapid depletion of the forest, and increase in fuel wood price. Besides, it imposes economic and environmental problems. Kuyu District also has the same problem like other places in Ethiopia.

1.2. General Objective

The main objective of this project was to design three box-type solar cookers from locally available materials and to test their performances.

Specific Objectives are:

To design three box type solar cookers.

To test the cooking rate of the three box types.

To compare the relative thermal energies generated in each of the boxes and at different times of a day.

1.3. Significance of the Study

Box cookers, if available, can offer a partial solution to multitude of cooking problems for people of low income. Therefore, this study was to introduce solar cooker which is safe and simple to operate and can satisfactorily be used for cooking in the presence of sunshine.

The introduction of a properly designed and improved solar cooker to the market in mass scale, can supplement the cooking energy requirement of several millions of people and reduce deforestation and environmental problems associated with the use of firewoods and fossil fuels. This Thesis was proposed to reduce the high dependency on firewood and charcoal for cooking purpose and strain on the economy of the individual households.

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2. REVIEW OF LITERATURE

2.1. Solar Cooking Technologies

Solar cooking has been identified as an appropriate technology as it has numerous advantages such as no recurring cost, potential to reduce drudgery of firewood collection, high nutritional value of the cooked food and high durability of the cookwares (Muthusivagami *et al.,* 2010). Solar cookers are heat exchangers designed to use solar energy in the cooking process. All solar cookers use the basic principles of concentrating light and heat from the sun into a small cooking area, converting light to heat and trapping the heat by isolating the air inside the cooker from the air outside the cooker using the greenhouse effect.

2.2. Solar Box Cookers

The solar box cooker consists, largely some type of heat trapping enclosure. Quite often , this takes the form of a box made of insulating material with one face of the box fitted with a transparent medium, such as glass or transparent plastic. This allows the box to take advantage of the greenhouse effect and incident solar radiation cooks the food within the box. The ability of solar cookers to collect sunlight is directly related to the projected area of the collector perpendicular to the incident radiation. For example, a large box with a glass lid will function as a solar box cooker but the losses due to heat loss over a larger surface area will, at least partially, offset the gain of having a large collector surface. Instead, what is typically done is to create an insulated box with a glazed surface cover and use reflectors to increase the apparent collector area. These reflectors can be made from variety of materials and their primary purpose is to reflect sunlight through the glazing material and into the cooking space inside of the box (Ademola and Rahman, 2013). Hot solar box cookers are simple in terms of fabrication, handling, operation, cheap and effective with minimal attendance required during the cooking process (Hussein *et al.,* 2008; Muthusivagami *et al*., 2010).

2.3. Thermodynamics of the Cooker System

From thermodynamic point of view the function of a solar box cooker is to trap and contain the heat of the sun inside it and to transfer the heat to the cooking pot as efficiently as possible. The heat retained inside the insulated box with a transparent cover is based on the greenhouse effect.

The light energy (which is short wave energy) that enters the cooker through the transparent top cover is absorbed by the black pots and the black bottom metal plate. The shortwave light energy is then converted into long wavelength heat energy and radiated from the interior materials. Most of this radiant heat energy is trapped inside the cooker and can (mostly) not radiated back out because of its longer wavelength. Although the transparent cover traps most of the radiant heat, some does escape directly through the lid (Dincer and Cengel, 2001).

2.4. Glass Cover

Type of the glass cover is an important factor affecting the percent of radiation transmitted to the absorber. The reason of using Pyrex can be explained as the behavior of the glass below 2.5 microns. Pyrex glass can transmit almost 91% of the incident (shortwave) radiation while not allowing long wave radiation emitted by the absorber. Some of the common glazing materials are given in Table 1.

Table 1.Transmissivity, absorptivity and reflectivity of glazing materials (Saying, 1979).

Glass	Transmissivity	Absorptivity	Reflectivity
High transparent pyrex	0.90	0.02	0.08
Common window glass	0.87	0.04	0.09
Double window glass	0.76	0.08	-

2.5. Solar Reflector

A good designed solar cooker need to be able to direct the greatest possible amount of sun light rays to the food. Moreover, it should also accommodate for the sun varying position and capture enough light to cook the food. This can be done by incorporation of reflector. The materials used for reflection vary with the region and resources available. Reflective materials that will be used include mirrors, aluminum foil, aluminum siding and certain types of metallic paint. However, different types of models of solar cooker will require different design for its effectiveness.

Table2. Solar reflectance values for reflector materials (Goswami *et al*., 1999).

Materials	Visible light Reflectance	Infrared reflectance-range
Silver (unstable as front surface mirror)	0.94 ± 0.023	
Gold	0.76 ± 0.03	
Aluminized acrylic, second surface	0.86	
Various aluminum surfaces	0.82-0.92	(0.7-1000)µm
Copper	0.75	
Back-silvered water-white plate glass	0.88	
Aluminized type-C Mylar (from Mylar side)	0.76	

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3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted at Kuyu District of North Shoa Zone of Oromia Regional State, Ethiopia located at 156 kms North West of Addis Ababa on the main road toward Gojjam. The District lies in the coordinate of $9^0$30' N altitude and 38^0 40' E longitude.

3.2. Materials

Materials used include: wooden box, thermometer, stopwatch, dark colored objects, insulation material, hinge, pots, measuring tape, glue, transparent glass, aluminum foil, and other materials to attach the boxes.

3.3. Experimental Design

Three box type solar cookers were designed and the boxes were constructed from locally available materials. The three prepared boxes had the same size and area. Then, the three boxes of smaller size were prepared and inserted inside the bigger boxes for insulation. Black metal sheet was used to line it inside the smaller boxes. Thermal insulation: the space between the outer and inner box was filled with insulating materials (sagatura) to reduce heat losses from the cooker. The first BTSC ($BTSC_1$) was covered with a single transparent glass and was without a reflector. The second BTSC ($BTSC_2$) was covered with double transparent glass. Insulator box was on the outside of the black coated box, and it too was without a reflector. The third type ($BTSC_3$) was similar to the second type except this one had two reflectors that could be adjusted. The reflector was adjusted depending on the direction of the sun. The insulator boxes were made from wood.

(a) (b)

Figure1. (a) actual box type solar cooker and (b) skech of the box.

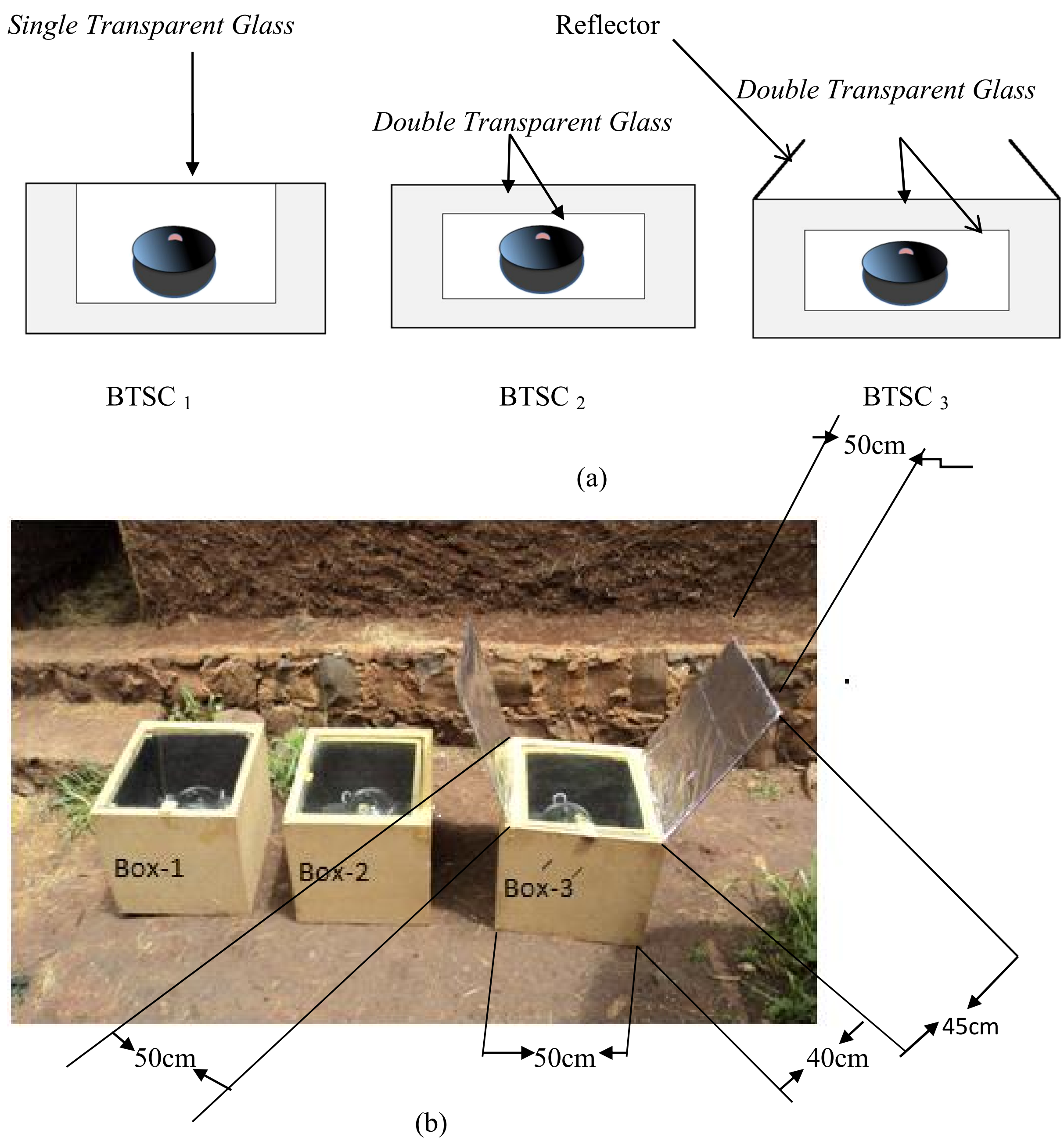

Figure 2. (a) Sketches of the three boxes and (b) Box-type solar cookers

The absorber part of the box was painted black and black painted pots were placed inside the box type solar cookers. These pots were also painted black on the outer surface so that they could also absorb solar radiation directly. Insulating material (sagatura) was inserted on five sides while the sixth side was fitted with a transparent glass. Glass allows the box to take advantage of the greenhouse effect and the incident solar radiation cooks the material in the box. The general design description of the box type solar cookers is listed in Table 3.

Table 3. Material used for the construction of box type solar cookers**.**

Component	Material	Dimension
Outer box	Wooden board	12 mm thick
Inner box	Wooden board	12 mm thik
Transparent glass	Common glass	4 mm thick
Vessel	Steel	1.2 mm thick
Insulator	Sagatura	----
Absorber plate	Black painted sheet metal	1 mm thick
Reflectance	Aluminum foil	0.6 mm thick

3.4. Data Collection

Solar cooker performance experiments were conducted two times each in May and June, 2016. Having suitable clear sky days were a good opportunity to conduct the experiment. During the experiment, ambient air temperature, base plate temperature, water temperature and sand temperatures were measured. For the water heating tests, three black painted pots of capacity 200 ml (0.2 kg) placed on the absorber plate of the three boxes of solar cooker. The sand for the experiment was collected locally and the mass of sand used for the testing were 1.3kg in each pot. The insulator (sagatura) was inserted between the inner and outer boxes has a mass of 3.30 kg at 5 cm gap. The outer box had area of 50 cm×50 cm and 40 cm deep with insulation and the inner box had area of 40 cm × 40 cm and 26 cm deep. The area of transparent glass, aluminum reflector and pots cooking were 45 cmx45 cm, 45 cm x 50 cm and 17 cm x 10 cm, respectively. The thermometer was immersed at 20 mm, 40 mm length in the water and in the sand in the cooking pots and secured at 6 mm height above the bottom, at the same location and direction. Thermometers were made to pass though the cooking pot lid inside a thermally nonconductive sleeve to protect the thermometer wires from bending and to avoid temperature extremes.

The experimental testing of the box type solar cookers was conducted at the testing area of Kuyu District. During each test, cooking boxes were placed side by side on the absorber of solar cooker and the same mass of water and sand were added to the pots. The performance of the boxes was evaluated by measuring both temperature and time to heat water in each of the boxes. The rise in temperature of water in each box was measured with thermometer, and stopwatch was used to record time. The test was repeated four times for each treatment. Measurements were made three times on day one between (11-12 am), the second between (1-2 pm) and the third between (3-4 pm). Measurements were conducted simultaneously to a void varability that may arise due to time difference, Figure 3 shows how measurement were conducted:

Figure3.Temperature and time measurements done simultaneonsly for three boxes.

3.5 Data Analysis

3.5.1. Boiling power

The change in water temperature for every two minute interval was multiplied by the mass, 0.2 kg and specific heat capacity, C_p (4186 J/kgK). The product was divided by 120 seconds contained in a 2-minute interval, yielding the boiling power, P, in Watts.

$$\frac{P=(T_f - T_i)MC_p}{120\ sec.} \qquad \text{eqn.(3.1).}$$

Where: T_f is the water temperature at the end of the 2 minute interval and T_i is the temperature at the beginning.

4. RESULTS AND DISCUSSION

During this experiment, ambient air temperature, base plate temperature, water temperature and sand temperatures were measured. Initial temperatures of water and sand were 20°C and 30°C respectively. To check the temperature of the box cookers, temperature was increased by heating water and the sand and the inial temperatures of the water and the sand were substructed to get the effective temperatures. The performances of the boxes were evaluated by based on temperature and time. The performance of $BTSC_3$ is compare with the $BTSC_1$ and $BTSC_2$. Actual temperatures of box type solar cookers and ambient temperatures were recorded every 2 minutes for all the boxes simulatneously.

4.1. Water Temperature Variations

The comparison between water temperatures in the box type solar cookers under the same test conditions are shown in Figure 4.

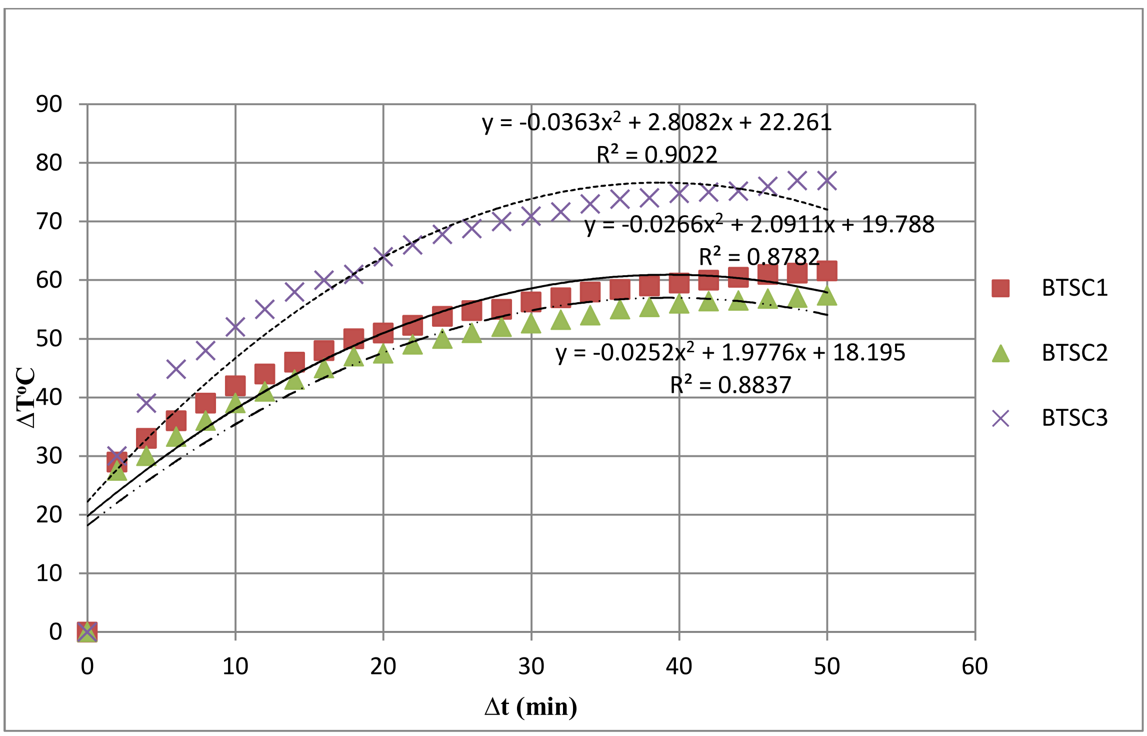

Figure 4. Plots of temperature versus time plot shown for water.

Figure 4 shows effective temperature versus time of boiling plots of the three box cookers. that various point of cooker during the heating test. $BTSC_3$ exhibited the highest effective temperature of over 75^{o}C in a matter of 40 minutes. The other two remained around 60^{o}C during the same time. The reflector has helped this box to reflect more light into the box while the double glass helped in producing the green house effect so as to surpass the other two by over 15^{o}C. The ambient temperature fluctuated between 22^{o}C and 25.3^{o}C during the test period. Since the contribution of the ambient temperature was the same for all the three boxes, there was no need to take this temperature into account.

$BSTC_1$ performed slightly better than $BSTC_2$ in this test. That means the benefit of the double glass without reflector was lost by shortwave reflecting power of the second glass. While the use of double glass is beneficial for keeping longwave radiation (heat) in the box, it at the same time limits the amount of shortwave radiation getting the box by almost 7%.

In all the three cases the water temperature leveled off after 40 minutes. In other words, the water in all the three boxes reached their optimum temperatures and further heating did not result in change of temperature. Hence, box cookers of these types are good for boiling water or warming food rather than for cooking.

4.2. Sand Temperature Test

When there is fear of evaporative loss of water replacing the water with sand is an appropriate measure. This avoids the heat energy loss in the form of latent heat especially as the temperature of water increases. The sand is also good heat storage. The weight of sand used in the test was 1.3 kg. The ambient temperature fluctuated between 20^{o}C and 27.6^{o}C during the test period. The initial sand temperatures in BTSCs were the same 30^{o}C. Figure 5 illustrates change temperatue change of the sand over time.

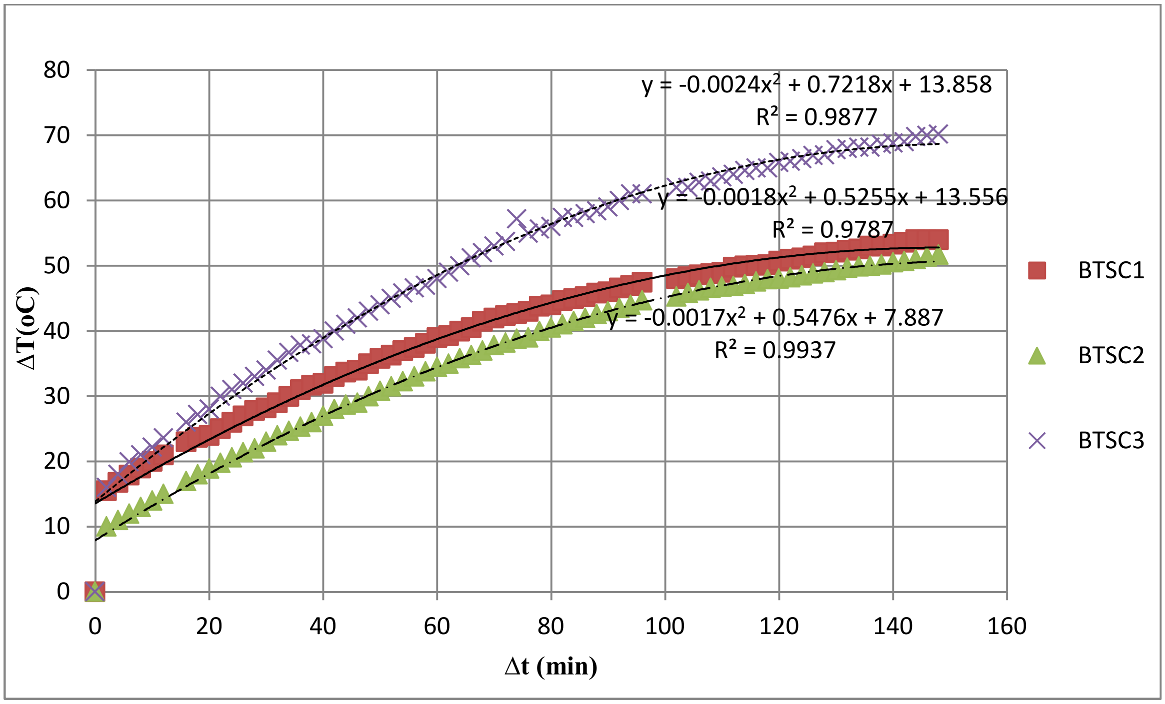

Figure 5. Plots of temperature versus time for sand.

Unlike water which took only 40 minutes to reach 77^{o}C for $BTSC_3$, time taken by sand to get close to this temperature was about four times. This is because of two reasons. First, the mass of sand used in the test was about six time the mass of water. Second, since the sand used was a very dry one heat transfer was by conduction heat transfer mechanism unlike convection in the case of water. Conduction heat transfer takes more time than convection heat transfer when the substance used is not a conductor of heat.

In this case as well $BSTC_3$ outperformed the other two by nearly 17^{o}C after nearly two and half hours. The difference between sand and water is that the temperature did not show leveling off even after 140 minutes. Temperature could have risen if more time were allowed. Cooking of high density food involves heat transfer of both conduction and convection and the use of sand in this case gives us a clue as to why it takes longer time to cook some food types.

During this test periodic overcast of weather also caused fluctuation in the solar radiation. There were cloud covers observed at 14, 98 and 100 minutes. This must have also resulted in partial heat loss during the intermittent times. The experimental result shows, the optimum sand plate effective temperature $BTSC_1$, $BTSC_2$ and $BTSC_3$ only got up to (54°C), (51.7°C) and (70.2°C), respectively. These temperatures were not the highest attainable temperatures for the cookers, but provide a comparison of the cookers tested under the same conditions and time. The $BTSC_3$ showed a good heat transfer to the cooking pot from the absorber plate, as well as reduction of heat loses due to good insulation and double glass cover and additional light using the refelactor. In the case of $BTSC_1$ and $BTSC_2$, the absorber plate absorbed the solar radiation transmitted through the glass cover only**.**

4.3. Temperature Tests of Empty pots

This test could be seen as no load test. The ambient temperature fluctuated between 22 °C and 24.8 °C during the test period. The initial temperatures of the BTSCs were the same, 25°C. The time duration for raising temperature from 25°C to 56°C, 57°C and 77°C were observed in about 50 minutes, for $BTSC_1$, $BTSC_2$ and $BTSC_3$, respectively. The results are summarized in Figure 6.

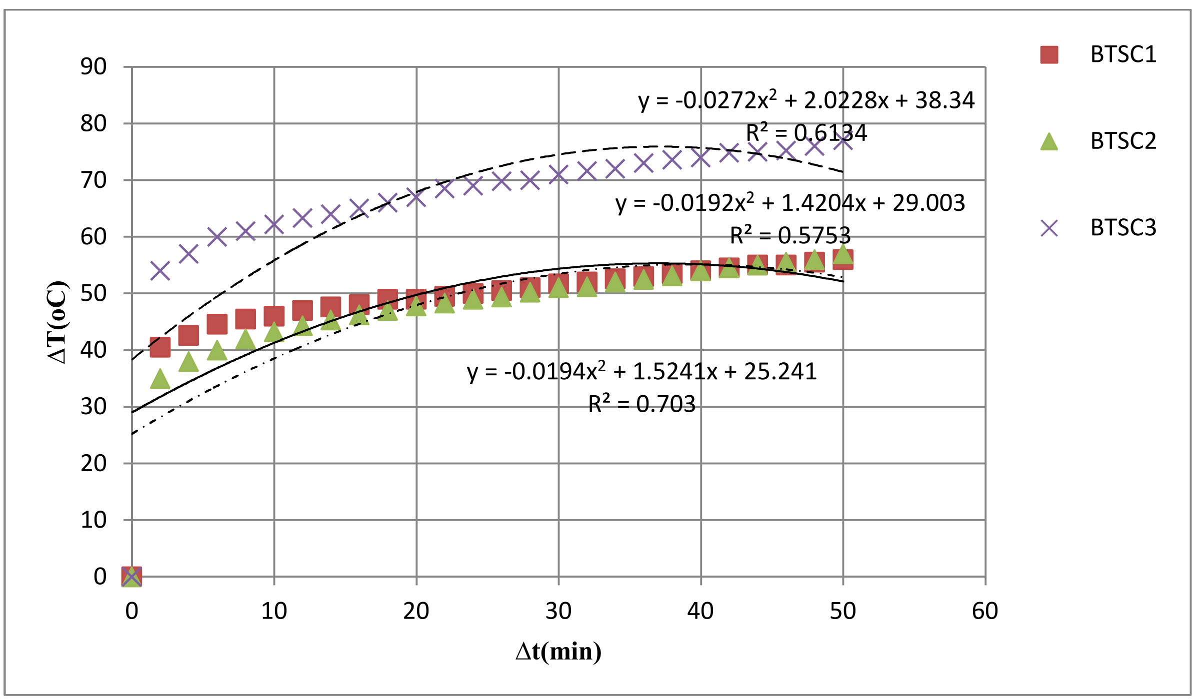

Figure 6. Plot of temperature versus time plot of empty pot

Figure 6 shows that even when empty the boxes showed the same trends in temperatre increment. However, there were weaker quadratic fits as observed in their R^2 values. This were due to easy heat losses from the plates when there were no heat retaining substances in the pots. In this case the temperature of the $BTSC_2$ was higher than that of $BTSC_1$ because of higher heat retaining ability of $BSTC_2$ double glass cover than the single glass of $BTSC_1$.

4.4. Solar Boiling power

Table 4 shows the calculated results of the boiling power of the constructed solar cookers. The results of the boiling power of the three different solar cookers: $BTSC_1$, $BTSC_2$ and $BTSC_3$ were found to be 429.25, 400.5 and 537.2 W, respectively. In all conditions the boiling power of the $BTSC_3$ was higher than that of the two BTSCs. This explains the benefit of reflectors over the covers be it single or double.

Table 4**.**Calculated results of the cooking power of the constructed solar cookers

Solar cooker	Cooking power (W)
$BSTC_1$	429.25
$BSTC_2$	400.5
$BSTC_3$	537.2

5. CONCLUSION

Three box type solar cookers were designed and the boxes were prepared from locally available materials. The third box type solar cooker was found to provide adequate temperature needed for boiling water and heating sand and reached a maximum effective temperature of 77 ^{o}C for water and sand though at different times because of the different masses of the two substances. $BTSC_3$ exhibited the highest temperature out of the three BTSCs. This is due to the box of absorber plate by solar radiation transmitted through the upper double glass cover and radiation reflected towards the absorber plate by the reflector assembly. In the case of $BTSC_1$ and $BTSC_2$, the absorber plate absorbed the solar radiation transmitted through the glass cover only.

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7. APPENDICES

Appendix Table1.Water heating test using three-box cookes Date:23/05/2016

		Temperature in ^{o}C		
Time (min)	Ambient temp.	BTSC1	BTSC2	BTSC3
12:30am	22	20	20	20
12:32	22	49	47.5	50
12:34	23	53	50	59
12:36	24	56	53.3	64.8
12:38	24	59	56	68
12:40	24.3	62	59	72
12:42	24.9	64	61	75
12:44	24.7	66	63	78
12:46	25	68	65	80
12:48	25	70	67	81
12:50	25.2	71	67.5	84
12:52	25	72.3	69	86
12:54	25.3	73.8	70	87.8
12:56	25	74.8	71	88.8
12:58	25	75	72	90
13:00	24.8	76.3	72.6	90.9
13:02	25	77	73.2	91.6
13:04	25	78	74	93
13:06	25	78.4	75	93.8
13:08	25	79	75.4	94
13:10	24.7	79.5	76	94.8
13:12	24.5	80	76.4	95
13:14	24.9	80.5	76.5	95.2
13:16	25	81	76.8	96
13:18	25	81.2	77	97
13:20	25.1	81.6	77.4	97

Appendix Table 2. Heating Sand Temperature Test Date:2/6/2016

Time (min)	Ambient temp.	Temperature in °C		
		BTSC1	BTSC2	BTSC3
11:48am	20	30	30	30
11:50	20	45.5	40	46
11:52	22	46.8	41	48
11:54	22.8	47.9	42	49.9
11:56	24	49	43	51
11:58	23.3	50	44	52.2
11:00	25	51	45	53.6
12:02	cloud	cloud	cloud	Cloud
12:04	24	53	47	56
12:06	24.5	53.7	48	57.2
12:08	24.6	54	48.9	58
12:10	25	55	49.8	60
12:12	25.5	56	50.6	61
12:14	26	57	51.4	62
12:16	26	57.8	52	63
12:18	26.3	58.2	53	64
12:20	24.2	59	54	65.5
12:22	24	60	54.7	66.7
12:24	25	61	55.3	67.8
12:26	24	61.7	56	68
12:28	25.5	62	57	68.8
12:30	26.4	63	58	70
12:32	27	63.7	58.7	71
12:34	27	64	59	72
12:36	26.6	65	60	73
12:38	26.6	65.8	60.8	74
12:40	26	66.3	61.5	75
12:42	26	67	62.3	75.8
12:44	26	67.5	63	76.6
12:46	25	68.1	63.8	77
12:48	24.8	69	64.5	78
12:50	24.5	69.3	65	79
12:52	24.5	70	65.8	80
12:54	26.5	70.5	66.3	81.2
12:56	26.5	71.5	67	82

12:58	26.7	72	67.8	83
13:00	27	72.4	68.2	83.7
13:02	27.2	72.7	68.8	84.2
13:04	27.6	73	69	85
13:06	27	73.8	70	85.6
13:08	27.4	74	70.5	86
13:10	27	74.7	71	87.4
13:12	26	75	71.5	87.4
13:14	25.6	75.3	72	88
13:16	25	75.8	72.6	88.4
13:18	25.2	76	73	89
13:20	27	76.6	73.5	90
13:22	27	77	74	91
13:24	27	77.5	74.7	91
13:26	cloud	cloud	cloud	Cloud
13:28	cloud	cloud	cloud	Cloud
13:32	25	78	75.3	92
13:34	25	78.3	75.8	92
13:36	25.4	78.6	76.2	92.8
13:38	25	78.8	76.6	93
13:40	25.2	79	76.8	93.6
13:42	25.1	79.8	76.9	94
13:44	24	80	77.2	94.6
13:46	24.2	80.1	77.6	95
13:48	23.7	80.2	77.9	95
13:50	23	80.7	78	95.8
13:52	24	81	78.2	96
13:54	23.5	81.2	78.5	96.4
13:56	23.5	81.5	78.8	96.9
13:58	23.7	82	79	97
14:00	24	82.1	79.3	97.8
14:02	24	82.4	79.7	98
14:04	24.5	82.6	79.9	98.2
14:06	24.8	83	80	98.2
14:08	25	83	80.2	98.6
14:10	25.5	83.2	80.5	98.8
14:12	26	83.6	80.7	99
14:14	26	84	81	99.8
14:16	26.7	84	81.4	100
14:18	26.3	84	81.7	100.2

Appendix Table3. Empty box temperature test Date:26/05/2016

Time (min)	Ambient temp.	Temperature in^{o}c		
		BTSC1	BTSC2	BTSC3
11:00am	22	25	25	25
11:02	22	65.5	60	79
11:04	22.5	67.6	63	82
11:06	22.6	69.6	65	85
11:08	23	70.5	67	86
11:10	23	71	68.2	87.2
11:12	23	72	69.3	88.2
11:14	22.7	72.6	70.3	89
11:16	23	73	71.2	90
11:18	23.2	74	72	91
11:20	23	74	72.8	92
11:22	23.4	74.5	73.3	93.5
11:24	23	75	74	94
11:26	23.3	75.5	74.4	94.8
11:28	23.3	76	75.2	95
11:30	23.7	76.7	76	96
11:32	23.5	77	76.2	96.6
11:34	23	77.6	77	97
11:36	23	78	77.5	98
11:38	23.2	78.5	78.1	98.6
11:40	23.7	79	79	99
11:42	24	79.5	79.5	99.8
11:44	24.2	80	80	100
11:46	24.5	80	80.5	100.2
11:48	24.5	80.5	81	101
11:50	24.8	81	82	102