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Comparative Analysis on Solar Cooking Using Box Type Solar Cooker with Finned Cooking Pot

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Abstract: *A comparative investigation was conducted using a box type solar cooker with two different cooking pots at the testing area of so KO to Energy Research Centre, UsmanuDanfodiyo University. The two potsare identical in shape and volume with one of the pots external surface provided with fins. The result of two tests (water heating and boiling test) revealed that 75cl of water was raised to 95^{o}Cin 112 and 126 minutes for finned and unfinned cooking pot respectively. These figures represent 11% reduction in heating time. Similarly 0.3kg of rice was cooked in 120 and 150 minutes for the finned and unfinned cooking pots respectively. This clearly demonstrates that fins improved the heat transfer from the internal hot air of the cooker toward the interior of the pot where the water and rice to be heated and cooked were kept.*

Keywords: *solar heating, thermal insulation, concentrating solar cooker and thermal performance*

Significance of the Research

The solar cookers if available can offer a partial solution to multitude of cooking problems face by people of low income. A properly designed and improved cooker if introduce in 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 fossil fuels Solar cooker which is safe and simple to operate can satisfactorily be used for cooking in the presence of sunshine.

I. Introduction

Solar energy is the energy from the sun. The sun generates energy ina process called nuclear fusion. During this process four hydrogen nuclei combine to become helium atom with the release of energy. This energy is emitted to the space as solar radiation. A small fraction of this energy reaches the earth. Today solar energy is used in various applications such solar heating, distillation, drying, cooking etc. To cook food for nourishment is fundamental to any society and these require the use of energy in some form. The use of solar energy to cook food presents a viable alternative to the use of fuel wood, kerosene, and other fuels traditionally used in developing countries for the purpose of preparing food. Increased in the awareness of the global need for alternative energy source has led to proliferation of research and development in solar cooking. Solar cooking can be used as an effective mitigation tool with regards to global climate change, deforestation, and economic debasement of the world's poorest people. Solar Energy has tremendous advantages in tropical country like Nigeria because of it abundance and sustainable source of energy. The use of solar cookers will have a great potential of reducing the suffering of many people from the shortage and high cost of fossil and other sources fuels. It will also reduce the tedious task faces by rural women in search of fire wood for cooking. Several factors including access to materials, availability of traditional cooking fuels, climate, food preferences, and technical capabilities: affect people's perception of solar cooking. It is in the light of this that the author decided to investigate the effect of solar cooking using box type solar cooker with finned cooking pot. The purpose of the fins is to improve heat transfer from the cooker surface to the surrounding. Fins can be thought as an extension of the surface by adding additional surface area which enables additional heat flow to and from the medium it is in contact.

1.1.1 Description of Box type solar cooker and the cooking Pot

The solar cooker used in this investigation is the box type solar cooker developed at Sokoto Energy Research Centre, Usmanu Danfodiyo University. The cooker has a dimension of 0.5m by 0.5m by 18m, the sides and bottom of the tray are encased in wooden box. The clearance between the galvanized iron sheet and encasement is filled with 5cm foam to provide thermal insulation, the tray consist of movable doubled glass cover hinged to one side of the incasing at the top. The plate and the experimental set up of the cooker is shown in fig 1. The cooker was exposed to solar radiation. The absorber consist of a galvanized iron sheet painted black with thickness of 4mm. the photograph of the box solar cooker is shown in fig 1.For the purpose of this investigation, two cooking pots were used. They are made up aluminum painted black, are cylindrical in shape and have plat base. Both the cooking pots have identical lid, with a diameter of 14cm and height of 7cm.the lateral external surface of one of the cooking pot was provided with fins made of galvanize iron painted black. The fins used are rectangular in shape with a cross reaction. (5.5cm by .05cm) and have a length of 2.2cm, spaced at 1.5cm. (Arezki Harmin, 2008). The photograph of the finned and un finned pots were shown in figure 2. Arriving global solar radiation was focused on the solar cooker. For the purpose of this investigation boiling test and cooking test were conducted. Dasin et al 2011.

In Nigeria and many other developing countries commercial fuels like coal, kerosene, cooking gas and electricity are very expensive beyond the reach of common man. Majority of the people depend on fuel wood for cooking purposes. Cutting down of trees for fuel wood has led to fast and rapid depletion of our forest therefore increase fuel wood price which imposes

economic and social burden on the people as well as cause environmental and ecological problems. To date rural women in Nigerian and other developing countries use labor and waste considerable time of day in search of firewood to meet their cooking energy requirement. The necessity for the search for available and affordable alternative source of energy to supplement the use of firewood for food cooking cannot be over emphasized. Solar energy through solar cooking offers a possible solution to these problems.

II. Literature Review

Several research works was, conducted in different areas of solar cooking ranging from thermal testing and performance evaluation of different types of solar cooking devices. Such devices include concentrating solar cookers, Parabolic solar cookers, panel solar cookers, hot box solar cookers, square and rectangular box type of solar cookers, Double exposure solar cookers ,solar cookers with thermal storage and many others by various authors with the aim of improving the efficiencies of these cookers. Some of the authors that work in this area include:(Ali, 2000)**,** Design and carried out series of test in nine days in other to make comparison of the Sudanese box type solar cooker against the Indian designs. Sudanese solar cooker showed a better thermal performance. (Ibrahim, 2005), Conducted an experimental testing of box type solar cooker using the standard procedure of cooking power. The box type solar cooker was tested to accommodate four cooking pots in tatna (Egypt) under prevailing weather conditions. The experiment was performed in July 2002.the cooker was able to cook most kind of food with an overall utilization efficiency of 26.7%.(.Ammer, 2005)**,** carried out research on the title, theoretical and experimental assessment of double exposure solar cooker. The solar cooker is exposed to solar radiation from the top and bottom sides with a set of plane diffuse refection is used to direct radiation on to lower side of the absorber plate.

The performance of the cooker and the convectional box type solar cooker were investigated. Result under the same prevailing conditions show that the absorbers of the box type solar cooker and the double exposure solar cooker attain a stagnation temperatures of 140^{o}C and 165^{o}C respectively.(hussein, 1997). Work on the performance of the box type solar cooker with an auxiliary heating. The performance of the cooker was studied and analyzed. It was done with the help of a built in heating coil inside the cooker. It was found that the use of auxiliary source allow cooking on most cloudy days.(Nahar, 2003), work on performance and testing of hot box storage solar cooker. Hedesigned fabricated and tested a hot box solar cooker with used engine as storage materials so that cooking can be performed in late evening. The performance and testing of a storage solar cooker was investigated by measuring stagnation temperatures and conducting cooking trials. The efficiency of the hot box storage solar cooker was found to be 27.5%.(Ngwuoke, 2003)**,** Design constructed and measured performance of plane - reflector augmented box type solar cooker. The solar cooker consists of aluminum plate absorber painted with black matt and double glazed lid. They predicted water boiling times using the two figures of merit compared favorably with the measured values, the performance of the cooker with plane reflector in place was improved tremendously compare to that without the reflector.EssanAbdullahi*et al* 2010**,** work on cylindrical solar cooker with automatic two axes sun tracking system. He design, constructed and operated a cylindrical solar cooker with two axes sun tracking. He carried out series of test during different days in the year 2008 from 8:30am to 4:30pm.the test show that the solar cooker can increase water temperature up to 90^{o}C. (D.Y Dasin, 2011)Carried out a performance evaluation of parabolic concentrator solar energy cooker in tropical environment in AbubakarTafawaBalewa University Bauchi Nigeria there study revealed that the stagnation temperature of 120^{o}C, 116^{o}C, and 156oc were achieved respectively on three different days between the month of June and July. The boiling test of water indicated that 1kg of water on three different days was raised to 95^{o}C 96^{o}C in 60-75 minutes. Food cooking showed that 200g of of white rice was cooked in 75 minutes,200g of parboiled rice was cooked in 75 minutes,200g of beans was cooked in 90minute and 800g yam was cooked in 75 minutes.(Danmallam, 2011)Developed and carried a performance evaluation of rectangular and square box type cookers at So ko to Energy Research Centre, Usmanu Danfodiyo University under the same environmental conditions found that the rectangular box type cooker performs better than the square type. For a given type of solar cooker it is possible to reduce the cooking time by carrying out modification on the shape of the cooking vessel. These modifications can improve heat transfer to the food through the pot walls (Arezki Harmin et al 2008).Gaur et al (1999) proposed a cooking vessel provided with a concave lid. Their experimental study showed a reduction of 10-13% in cooking time compared to and ordinary cooking vessel under the same conditions.

III. Experimentation

The experimental testing of the solar cooker was conducted at the testing area of Sokoto Energy research centre.. During each test, both cooking pot were placed side by side on the absorber of the solar cooker and loaded with the same mass of water 75cl at the same temperature for water heating test. The temperatures of' the water in each pot as well as ambient temperature and global solar irradiation were recorded at 15 minute intervals using amulti-channel data logger system. Global components solar radiation was measured using CM11 typepyranometer. Both the two potwere filled with water was placed in the cooker, and was closed with double glazing cover until test end. The cooker was manually oriented according to azimuth at an interval of 15 mm in order to collect a maximum of solar radiation.

IV. Results

4.1 Water boiling test

Table1: Temperature distribution at various point of cooker for heating test

Time	Ambient temp (°C)	Water Finned pottemp (°C)	Water in Unfinned pot temp(°C)	Plate temp (°C)	Solar radiation W/m2	Wind speed(m/s)
11:15	40.1	39.6	39.6	75.1	864	0.4
11:30	41.5	55.2	53.9	83.9	897	0.5
11:45	41.7	68.4	64.2	88.4	951	0.4
12:00	44.6	77.4	73.5	93.5	965	0.9
12:15	41.6	80.9	76.1	97.4	953	0.8
12:30	43.3	87.6	81.5	114.3	961	0.1
12:45	42.8	91.7	87.2	117.6	968	0.2
13:00	45.1	94.2	92.7	120.9	944	0.6
13:15	44.4	96.4	94.6	124.7	915	0.9
13:30	44.3	97.8	95.2	129.5	905	0.8

Table 2: result of water heating test 0.75 liters

Mean ambient temperature (°C)	42.9
Initial water temperature (°C)	39.6
Time of boiling with finned pot (Min)	112
Time of boiling with un finned pot	126
Reduction in time (min)	14
% reduction in Boiling time (Min)	11

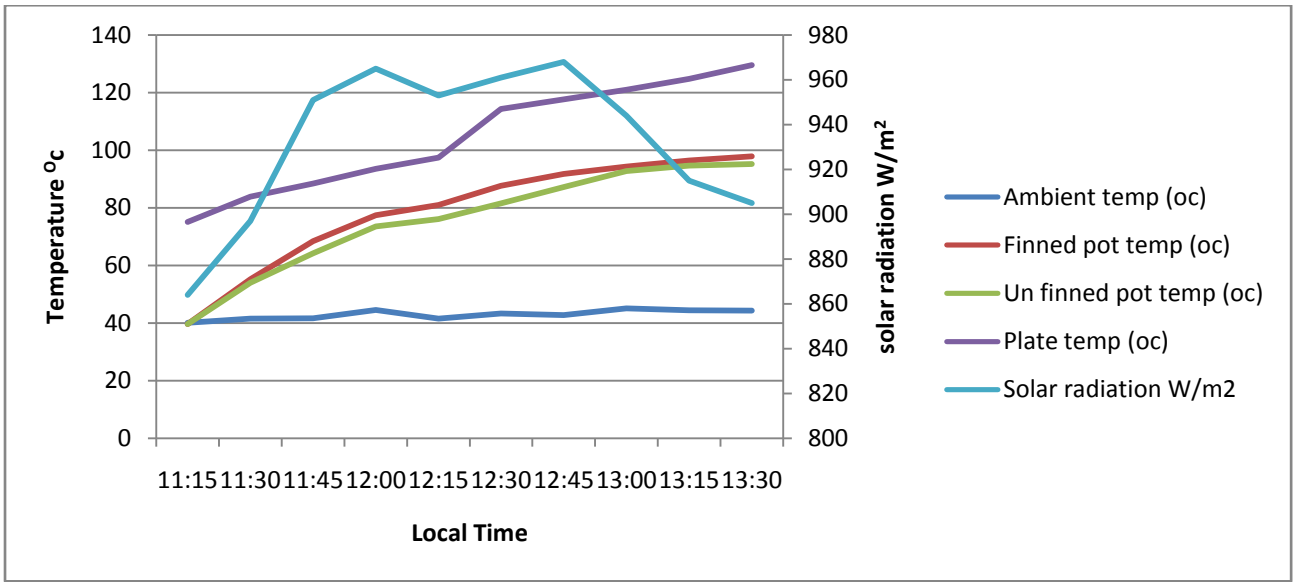

Fig 4: Water boiling test. Comparison between water temperature in the finned cooking pot and the water temperature in the UN finned cooking pot

Table 3: Temperature distribution at different times during the r rice cooking test on 28thFebruary, 2013

Time	Ambient temp (°C)	Finned pot temp (°C)	Unfinned pot temp (°C)	Solar radiation W/m2	Wind speed(m/s)
11:45	40.7	57.6	57.2	933	0.4
12:00	41.4	69.6	73.0	960	0.3
12:15	41.0	88.6	85.2	969	0,5
12:30	41.9	91.4	90.4	946	0.6
12:45	42.5	99.5	95.6	946	0.5
13:00	44.0	108.4	101.5	918	0.3
13:15	44.6	112.8	105.9	895	0.8
13:30	43.9	117.2	108.4	880	0.6
13:45	42:3	119.5	113.2	894	0.4
14:00	41:8	122.6	116.5	875	0.7
14:15	40.4	125.5	118.9	884	0.4

Table 4: Result of rice cooking test

Mass of the cooking pot	0.2kg
Volume of water	0.75l
Mass of rice	0.30kg
Mean ambient temperature(^{o}C)	42.2
Finned pot temperature at cooking time(^{o}C)	119.5
Un finned pot temperature at cooking time(^{o}C)	118.9
Time of cooking for finned pot (Min)	120
Time of cooking for un finned pot(Min)	150

V. Data Analysis and Discussion of Results

Fig. 4 shows the comparison between water temperature in the finned cooking pot and the water temperature in the unfinned cooking pot under the same test conditions on February 27th, 2013. It was found that the temperature of the water in the finned cooking pot was always higher than the temperature of water in the un finned cooking pot. The time taken for attaining boiling temperature (95 °C) by the two cooking vessels was 112 min for the finned, and 126 min for the un finned pot and finned cooking pot respectively.Table1: shows the various Temperature distributions at various point of cooker during the heating test. The ambient temperature fluctuates between 40.1^{o}C and 45.1^{o}C during the test period. The initial water temperature in the finned cooking pot and in the un finned cooking were the same 39.6^{o}C. The water in the finned cooking pot attained boiling temperature nearly 15 min earlier than time water in the unfinned cooking pot. The plate temperature for cooker under investigation was raised nearly 130^{o}C during the test period. For rice cooking test, table 3 shows the temperature distribution at different times during the rice cooking test on the 28th February, 2013. The ambient temperature fluctuate between 40.4^{o}C to 44.6^{o}C.it was also observed that the temperature on the finned pot is always higher than the temperature in the unfinned cooking pot throughout the period of the investigation.0.3kg of parboiled rice was cooked in 120min and 150 min for finned and unfinned pot respectively. The temperature of finned cooking pot at cooking time was 119.5^{o}C, while that of unfinned pot was 118.9^{o}C. The high cooking time could be attributed to observed openings around the glazing covers which lead to the heat lost in the cooker.

VI. Conclusion

The result of two tests (water heating and boiling test) revealed that 75cl of water was raised to 95^{o}C in 112 and 126 minutes for finned and unfinned cooking pot respectively. These figures represent an 11% reduction in heating time. Similarly 0.3kg of rice was cooked in 120 and 150 minutes for the finned and unfinned cooking pot respectively. The investigation has revealed that cooking time can be reduced by using a finned cooking pot. The reduction in cooking time is consistent with the increase of the heat transfer surface area by fins attached to the external surface of the cooking pot.

VII. Recommendations

Based on the investigation carried out the following recommendations are made:

i. Dimensions and geometry of the fins should be studied in more detail in order to optimize the performances of this kind of cooking pot.
ii. The investigation should be carried out at different season so as to understanding the cooking profile of various periods in the year.
iii. Manufacturers of cooking pot should produce cooking pot with fins to accommodate those who want to use them for solar cooking.
iv. Solar cooking should be encourage and popularize through mass production and distribution to students, rural dwellers and low income earners to supplement to high cost of convectional fuels such as kerosene, LPG ,Cooking gas and Fuel wood.

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