CONSOLFOOD 2018 – International Conf. on Advances in Solar Thermal Food Processsing…Faro-Portugal, 22-24 January, 2018

THERMAL PERFORMANCE EVALUATIONS, ENERGY SAVINGS AND PAYBACK PERIODS OF A BOX-TYPE SOLAR COOKER IN IBADAN, NIGERIA

Ademola K. Aremu* and Olaoluwa S. Awotunde
Agricultural and Environmental Engineering Department, Faculty of Technology, University of Ibadan, Nigeria….. *E-mail: ademolaomooroye@gmail.com

INTRODUCTION

The use and availability of solar cookers in Nigeria has been restricted to research institutions (Sambo, 2005) hence, the need for the effective dissemination of the technology to the teeming populace. For this to take place, there will be need to convince people on its functionality and economic viability. Hence, the objective of this work was to evaluate the thermal performance and economic viability of a box-type solar cooker in Ibadan metropolis, Oyo State, Nigeria.

Project Description: A family size solar box cooker capable of cooking for 4 to 5 persons was constructed. The constructed cooker has an aperture area of 0.25m^2. The constructed solar box cooker is as presented in Figure 1.

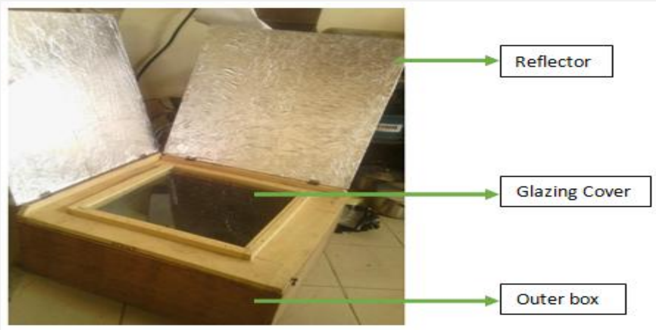

Figure 1: The Constructed Solar Box Cooker

ECONOMIC EVALUATIONS

The cost of operating each of the cookers was estimated per annum for all the cookers and was compared with the cost of combined usage of solar cooker with the existing cooker. Some of the financial parameters used by Kumar *et al.* (1995) were adopted in the financial evaluation of the solar box cooker. Other parameters such as Cumulative Cash flow (*CCF*) and Simple Payback Period (*SPP*) were also estimated. Savings per meal, S_i, was given by:

$$S_i = C_{oi} - C_{os} \quad (1)$$

Where: C_{oi} = the operating cost of fuel cooker; C_{os} is the operating cost of the solar cooker.

The cumulated cash flow, CCF, was calculated using:

$$CCF = -C_{CS} + NP_i \quad (2)$$

Where: C_{cs} is the cost of the solar cooker; *N* is the useful life of the solar cooker in years; P_i is the annual savings derived from using the box solar cooker. The Simple payback period *SPB*, was calculated using:

$$SPB = \frac{C_{CS}}{P_i} \quad (3)$$

Taking into consideration the time value of money with interest rate *r*, Net present value, NPV, of the project was given by:

$$NPV = -C_{CS} + \sum_{y=1}^{N} \frac{P_i}{(1+r)^y} \quad (4)$$

The discounted payback period *DPB* was given by:

$$DPB = \frac{\ln\left[\frac{1}{(1-rSPB)}\right]}{\ln(1+r)} \quad (5)$$

These were determined for each type of existing cooker in comparison with the solar cooker.

COOKING TEST RESULTS

Stagnation Temperature: The maximum absorber plate temperatures reached by the cooker on the three days were 126, 109.9 and 113.7^{o}C while their respective air temperatures were 113.9, 104.3 and 103.4^{o}C. Figure 2 shows the temperature trend in the solar box cooker temperature and the ambient temperature during the stagnation test. It shows a gradual and progressive rise in temperature until the peak is reached and then reducing over time. This same trend was also reported by Mohod and Powar (2011).

First Figure of Merit (F_1): The cooker had F_1 values ranging from 0.11 to 0.13. Though, these values are lower than the range reported by Aremu and Akinoso (2013), it can be classified as Grade A cooker according to the criteria given in IS 13429-1 (BIS, 2000).

Second Figure of Merit (F_2): In heating 1kg, 1.5kg and 2kg of water, the calculated F_2 were 0.30, 0.24 and 0.27 respectively.

Water Heating Test: The performance of the solar box cooker varied with the amount of water and the ambient condition. The solar cooker performed best in heating 1kg of water at an insolation of 851W/m^2. The temperatures attained in the three days were suitable for cooking.

Cooking Power: The cooker has the highest cooking power of 92.40W for 1kg of water while 97.65W and 72.80W were obtained for 1.5kg and 2kg respectively.

Standardized Cooking Power: When the cooking power was standardized to a cooking power of 700 W/m^2, highest cooking power was attained with 1kg of water at 85.56W. Cooking power of 80.18W and 56.91W were attained with 1.5kg and 2kg of water respectively.

Temperature Difference: For 1.5kg of water, the temperature difference ranged between 10.20 and 57.25^{o}C while 2kg water had a temperature difference ranging from 4.65 to 53.6^{o}C. The coefficient of determination between the standardized cooking power and temperature difference for 1.5kg water heating was 0.77.

Single Measure of Performance: Based on the regression equation, the standardized cooking power at temperature difference of 50^{o}C was 17.82W

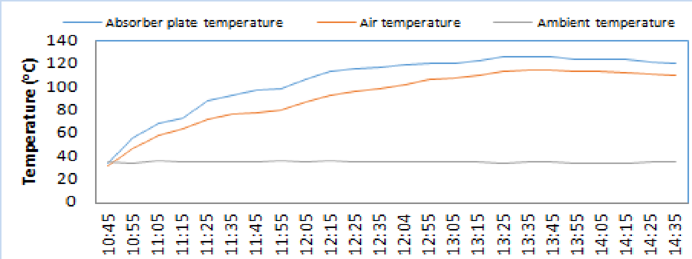

Figure 2: Temperature profile at stagnation test (29/12/2015)

Table 1: Estimated financial parameters of using the Solar Box Cooker as a supplementary with other existing cookers

Cooker Supplemented	Annual savings ($)	CCF ($)	NPV ($)	SPB (Months)	DPB (months)
LPG	109.47	491.09	348.33	7	7
Kerosene	58.86	238.13	161.35	12	13
Charcoal	72.15	304.48	210.40	10	11
Fuelwoood	77.87	334.57	231.55	9	10
Electricity	39.33	140.38	89.10	18	20

CONCLUSION

Thermal performance and economic viability of box-type solar cooker in Ibadan metropolis was investigated in this study. Use of box-type solar cookers has tremendous benefits of cost and energy savings over other cookers. There is therefore, need to intensity effort to disseminate information on the use of solar energy for cooking to the people especially the low-income rural dwellers. It is recommended as an alternative for cooking in the quest to make human activities go greener. Organizations, bodies and Government at all levels are enjoined to partner with the academics to ensure maximisation of the benefits derivable from using solar energy.

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