

# Performance Evaluation of 'Saradhaa' Hybrid Solar Box Cooker

Jeyagowri, R. and Gnanasakthi Jagadeesan

**Abstract**— Saradhaa' hybrid solar box cooker operating in dual mode of energy namely solar and electricity (HSBC) was designed and its efficiency was assessed in terms of time taken to cook selected food items using different methods of cooking, different modes of operation namely solar, electrical and dual mode and compared with the cooker 'D' (based on the results on available six solar box cookers in the market). The different cooking methods revealed that baking cake and biscuit took a maximum time (90 min) followed by boiling Bengal gram whole and cow pea (45 to 55 min). Roasting groundnut and green gram dhal required 40 to 45 min. Steaming of Idli and string hoppers (Idiapam) was possible in 20 to 25 min. Time taken to prepare a family meal in different modes of operation revealed that the cumulative time taken to cook a family meal of 777g of foods loaded together was found to be 2hr-30min in solar mode on a bright sunny day of 350C of ambient temperature and 909.81w/m<sup>2</sup> of solar insolation. When the foods were loaded together with the heater setting at 1200C for indoor cooking, dhal got cooked in 70 min followed by vegetable at 105 min and the complete cooking including rice was over by 130 min. The electricity consumption was estimated as 867w/hr. The cooking experiment in dual mode of solar and electricity indicated that the cumulative time required to prepare a meal was 2hr-25min.. It is hoped that this new model, which can be utilised in all seasons would find new vistas in the field of solar cooking technology.

**Keywords**— Performance evaluation, hybrid, solar box cooker, solar radiation, ambient temperature, food temperature.

## I. INTRODUCTION

The developing countries today consume 30 per cent of the world's total energy in domestic sector and will be 50 per cent by 2020 and probably 70 per cent in 2100. The energy requirement in domestic sector is 40 to 50 per cent of the total energy requirements in India today. Moreover the energy needs in the domestic sector are increasing annually at the rate of 8.1 per cent. An analysis of household energy consumption pattern reveals that the major use is for heating and cooking. Owing to the need for tapping solar energy especially for household cooking, and non-availability of low cost, compact, efficient and versatile cooker to be used during sunny and non-sunny hours of the day, a device for all days use in a year was developed. A novel 'Saradhaa' hybrid solar box cooker comparatively which conserves less time, portable, durable, easy to use and maintain, at an affordable cost were the significant features incorporated in the newly developed

cooker and its performance was analyzed with the following objectives:

- Assess the time taken to cook selected food items using different methods of cooking in the newly developed 'Saradhaa' hybrid cooker.
- Conduct cooking performance tests for the newly developed 'Saradhaa' hybrid cooker in different modes such as solar, electrical and dual modes of solar and electrical energy.

## II. MATERIALS AND METHODS

### A. Assessing the Performance Ability of the Newly Developed Hybrid Solar Box Cooker

A newly fabricated 'Saradhaa' hybrid solar box cooker was assessed for its performance ability. 'Saradhaa' cooker, a viable smart home technology was hybridized with electricity, for cooking food during non-sunshine hours and cloudy days suitable for an average family of four members. It was designed and fabricated with the best performed materials based on the test results and also from the study of existing available similar types of solar box cookers (Figure 1). This hybrid solar box cooker was made of Fibre Reinforced Plastic (FRP) outer body with the dimensions of 56.5cmx38.5cmx18.5cm and the copper tray for inner box having the floor area of 0.1584m<sup>2</sup>. The cover plate consisted of two toughened glasses of 3mm thickness with a spacing of 10mm in between them. The mirror was used as reflector having an area of 0.1664m<sup>2</sup>. White rock wool and yellow resin bonded glass wool of 40mm thickness was packed as an insulation material. The electrical backup of 400 wattage heating element and thermostat control were fitted in the solar cooker. The cost of the cooker is Rs `3000/- which can be procured at an affordable cost. These features made the cooker look unique and highly efficient compared to other cookers.

### B. Conducting Cooking Performance Test

The cooking performance test was carried out with the following aspects:

#### Cooking Methods

The different methods of cooking namely, boiling, steaming, roasting and baking were tried out for the feasibility of cooking in 'Saradhaa' hybrid solar box cooker. Cooking experiment was carried out by selecting two foods of 100g each under each method of cooking. The time taken to cook each food item under different cooking methods was recorded.

During the experimental days, the various factors such as ambient temperature, tray temperature, food temperature, solar radiation and sunshine hours were recorded.

### Cooking in different Modes

The cooking experiment was conducted in 'Saradhaa' HSBC in solar mode and indoor electrical mode.

### Outdoor Solar Mode

The foods namely rice, dhal and vegetable 100g each with standardized quantity of water were taken in a stainless steel copper bottom black painted container. The cooker was kept in the sunlight at 10 a.m. in the morning and oriented towards the South East direction. After preheating for half an hour, each food item was cooked separately in solar mode. The time taken to cook each food item was noted. The ambient temperature and solar radiation were also recorded. Likewise, all the food items were taken in three containers and loaded at a time in the cooker and allowed to cook. The cumulative times taken to cook all the three food items were recorded along with ambient temperature and solar radiation.

### Indoor Electrical Mode

Hundred grams of the same foods were cooked in Saradhaa in indoor mode by setting the heater element at 1000°C and 1200°C. The time taken to cook each food item in two different thermostat settings and the cooked food temperature were recorded. The energy consumed for cooking in terms of w/hr was assessed. Likewise all the three foods in three containers were cooked at a time. The cumulative time taken to cook the foods was recorded. The electrical energy consumption was also observed.

### Cooking a Family Meal

A family meal containing rice, dhal and vegetable were cooked at a time in solar cooker. The quantity of foods required for a meal to a family of four members (two adults and two school going children 12 years old boy and a 9 years old girl) was estimated as per the recommended Indian

Council of Medical Research (ICMR)(Table.1).

TABLE I: QUANTITY OF FOODS REQUIRED FOR A FAMILY MEAL

Food stuff	Quantity of food (g)				Total quantity (g)
	Adult man	Adult woman	School going children		
			Boy	Girl	
Rice	156	123	111	95	485
Dhal	13	13	20	20	66
Vegetable	70	63	50	43	226
Total	239	199	181	158	777

The foods such as rice, dhal and vegetable were cooked in solar mode, indoor electrical mode and outdoor dual mode of solar and electrical energy in three separate containers. The heater setting was kept at 1200°C during the electrical mode of operation. The cumulative time taken to cook foods for a meal was recorded for each mode of operation as per the cooking procedure adopted earlier.

## III. RESULTS AND DISCUSSION

### A. Cooking Performance of Hybrid Solar Box Cooker

The cooking test consisted of cooking foods in different methods, cooking in solar and indoor electrical mode and preparing family meal under three modes of operation.

### Cooking Methods

The different cooking methods such as boiling, steaming, roasting and baking were carried out in 'Saradhaa' HSBC with the selected two foods of 100g each under each method of cooking. The time taken to cook the selected foods under different methods of cooking, the temperature of cooked food and the corresponding solar energy parameters are presented in Table 2:

TABLE II: TIME TAKEN TO COOK THE SELECTED FOODS BY DIFFERENT METHODS

Cooking method	Foodstuff	Time taken	Ambient temperature (°c)	Tray temperature (°c)	Food temperature (°c)	Solar radiation (cal s/cm <sup>2</sup> /day)	Sunshine hours
Boiling	Bengal gram whole	45	33	112	97	492.8	11.0
	Cow pea	55	32	107	94	462.0	10.8
Steaming	Idli	20	32	109	92	485.1	11.2
	String hoppers (idiappam)	25	32	111	97	462.0	10.8
Roasting	groundnut	40	32	110	87	462.0	10.8
	green gram dhal	45	32	107	99	446.6	10.5
Baking	Cake	90	35	112	98	477.4	10.8
	Biscuit	95	35	109	92	462.0	10.5

It was observed that baking cake and biscuit took a maximum time (90 to 95 min) followed by boiling Bengal gram whole and cow pea (45 to 55 min). Roasting groundnut and green gram dhal required 40 to 45 min. Steaming of Idli

and String hoppers (idiappam) was possible in 20 to 25 min. During the experimental period, the ambient temperature, solar radiation and sunshine hours ranged from 300°C to 350°C, 446.6 to 492.8 cal/cm<sup>2</sup>/day and 10.5 to 11.2 hours per day respectively. The tray temperature during cooking ranged from 1070°C to 1120°C while the cooked food temperature was 870°C to 990°C, showing the effective heat inside the cooking tray.

### B. Cooking in Different Modes of Operation

#### Solar Mode

Table 3 shows the time taken to cook foods in 'Saradhaa' hybrid solar box cooker by solar mode when the solar radiation was above 430 cal/cm<sup>2</sup>/day and the ambient temperature was in the range of 330°C to 350°C.

TABLE III: TIME TAKEN TO COOK FOODS IN 'SARADHAA' COOKER BY SOLAR MODE

Foodstuff	Quantity (g)	Time taken (min)	Tray temperature (°C)	Food temperature (°C)	Ambient temperature (°C)	Solar radiation (cal/cm <sup>2</sup> /day)
<b>Loaded individually</b>						
Rice, parboiled	100	50	145	99	33	462.0
Red gram dhal	100	45	140	99	34	477.4
Vegetable - French beans	100	35	140	99	34	475.6
<b>Loaded together</b>						
Rice, dhal and Vegetable	300 (100g each)	75	135	99	35	486.8

When foods were cooked individually by keeping one container at a time, rice took the maximum of 50 min followed by dhal (45 min) and vegetable (35 min) during which the tray temperature was recorded between 1400°C and 1450°C and the food temperature was 990°C. When all the three foods were loaded in the cooker in three separate containers with the total weight of 300g, the time taken to cook all the three foods was found to be 75 minutes only. The cooked food temperature was recorded as 990°C while the tray temperature was 1350°C. It was inferred from the findings that a time saving of 42 per cent could be accrued when the foods were cooked together instead of individually.

#### Electrical Mode

The cooking experiment was also conducted in 'Saradhaa' hybrid box cooker at indoor electrical mode with 400 watts capacity of heating element by setting the thermostat control at 1000°C and 1200°C level for cooking rice, dhal and vegetable, individually and all the foods loaded together. The observations recorded are shown in Table 4:

TABLE IV: TIME TAKEN TO COOK FOODS IN 'SARADHAA' COOKER BY ELECTRICAL MODE

Foodstuff	Quantity (g)	Heater setting (°C)	Time taken (min)	Food temperature (°C)	Energy consumed (w/hr)	Heater capacity (w)
<b>Loaded individually</b>						
Rice, parboiled	100	100	50	98	333	400
		120	40	99	267	
Red gram dhal	100	100	40	96	267	
		120	35	99	233	
Vegetable - French beans	100	100	30	89	200	
		120	25	92	167	
<b>Loaded together</b>						
Rice, dhal and vegetable	300	100	100	96	667	
		120	85	97	567	

The time taken to cook rice in electrical mode with heater setting at 1000°C was found to be 50 min followed by dhal (40 min) and vegetable (30 min) with an electrical consumption of 333 w/hr, 267 w/hr and 200 w/hr respectively. When foods were cooked at 1200°C heater setting, the time taken was lesser by 10 min in the case of rice and five minutes for dhal and vegetable with the lesser consumption of electricity (34 to 66 w/hr). When rice, dhal and vegetable were loaded at a time in three separate containers at 1000°C, the cooking time was recorded as 100 min with 667 w/hr energy consumption while it was 85 min with the lesser wattage of 567 w/hr at 1200°C heater setting. When the foods were loaded together in electrical mode, 15 to 17 per cent of time and electrical energy could be saved on comparison with individual loading.

#### Cooking a Family Meal in Different Modes of Operation

A meal comprising of rice (485g), dhal (66g) and vegetable (226g) was prepared for an average family of four members as per ICMR recommended allowances in 'Saradhaa' hybrid solar box cooker in solar, electrical and dual modes of operation. The time taken to cook a family meal in different modes of operation is given in Table 5.

TABLE V: TIME TAKEN TO PREPARE A FAMILY MEAL IN DIFFERENT MODES OF OPERATION

Mode of operation	Foodstuff	Quantity (g)	Heater setting (°C)	Tray temperature (°C)	Time taken (min)	Food temperature (°C)	Ambient temperature (°C)	Solar insolation (w/m <sup>2</sup> )	Energy consumed (w/hr)	Heater capacity (w)
Solar	Rice, dhal vegetable	777		130	150	99	35	909.81	-	-
Electrical	Dhal	66	120	135	70	98	-	-	467	400
	Vegetable	226		148	105	98	-	-	700	
	Rice	485		140	130	98	-	-	867	
Dual	Dhal	66	120	140	35	98	32.5	569.62	266	400
	Vegetable	226			85	98				
	Rice	485			145	98				

## IV. CONCLUSION

Newly developed Saradhaa cooker had lot of unique features such as compact in size, portable in nature with affordable price of Rs`3000/- and could be used for a family of four members and a family meal can be cooked at a time in this cooker in solar, electrical and in dual modes. Two castor wheels attached in the front side bottom made the cooker movable easily. Two knobs placed at rear side bottom helped the cooker to be stable at the time of use. Different methods of cooking were possible in this cooker. The high thermal efficiency achieved in the developed 'Saradhaa' HSBC model would help in reducing the drudgery in cooking and saves the homemakers time and energy. It is hoped that this new model, which can be utilized in all seasons would find new vistas in the field of solar cooking technology.

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Fig. 1: 'Saradha' Hybrid Solar Box Cooker