MULTIPURPOSE SOLAR OVEN

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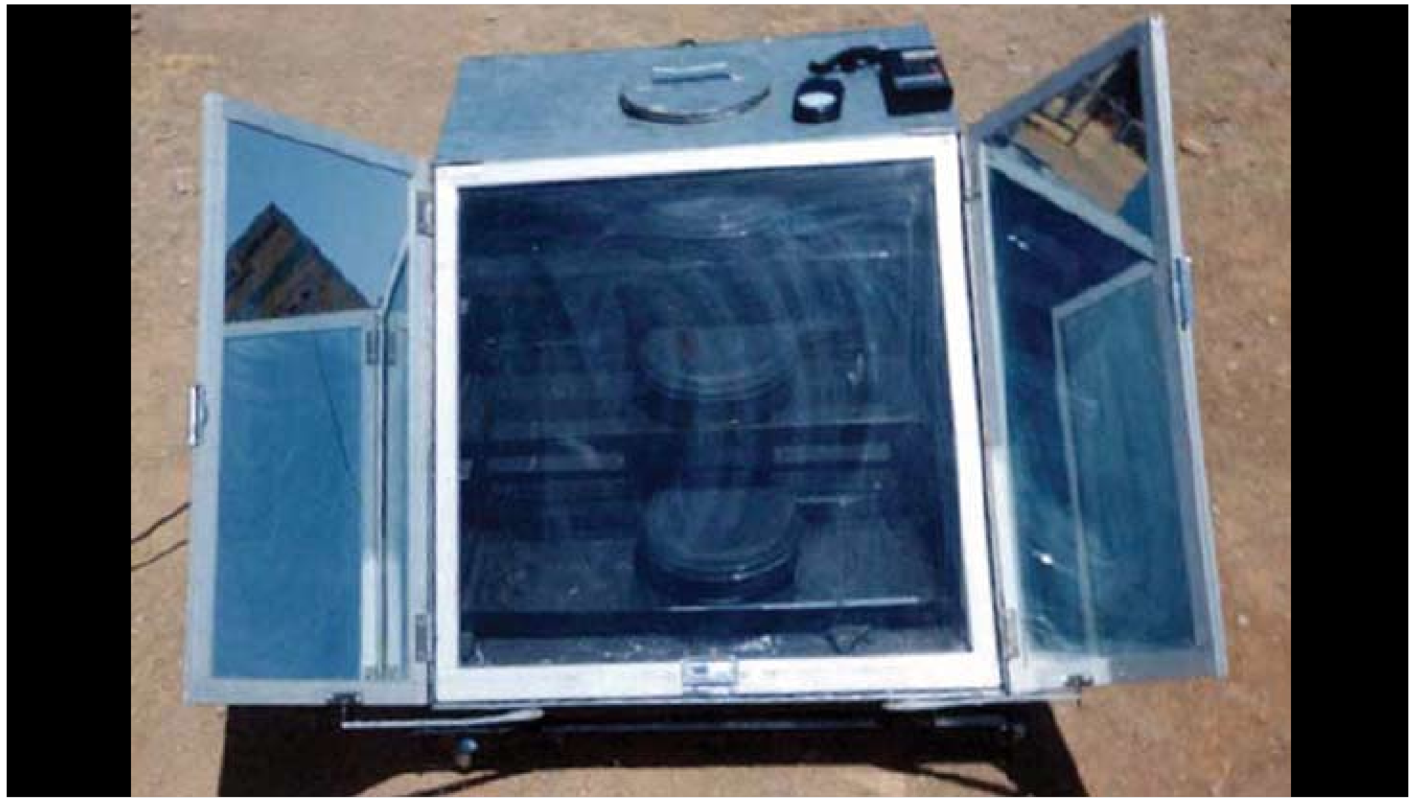
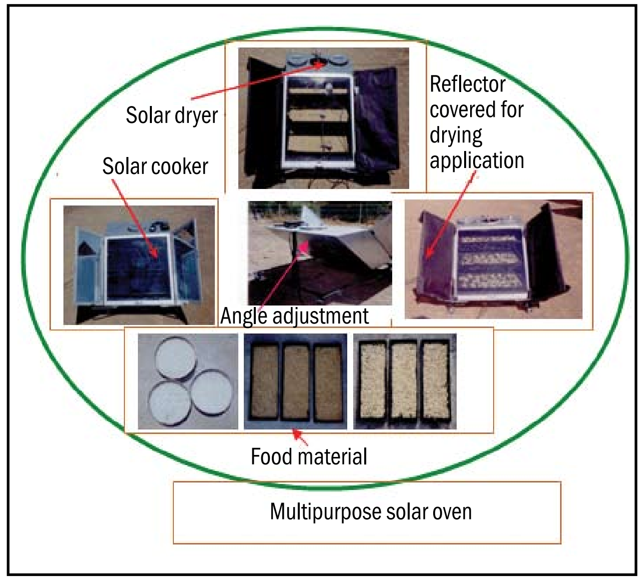


Introduction

Solar drying and cooking are a feasible proposition in most parts of India where solar radiation is quite abundant. India receives on an average of 5 kWh/m^2/day for about 300 days per year. This energy can be utilized for various thermal applications, including drying and cooking. Solar energy appliances are employed for various uses for single operation and they remain idle when not in use. If the solar appliances are developed to perform more than one function, their versatility and reliability can be increased without reducing the quality of the products or polluting the environment. Keeping this in view, a multipurpose solar oven has been designed, developed, and tested at the Department of Renewable Energy Sources, College of Technology and Engineering in Udaipur, Rajasthan. This oven is capable of cooking food and drying food products and vegetables for meeting the requirement of about 5–6 people.

System description

This solar oven is based on hotbox principle and has two reflectors. It consists of a collector unit with a net effective area of 0.36 m^2 as shown in Figures 1 and 2. It is fundamentally based on two-process—hotbox principle through the application of solar energy and natural circulation of dried air from dryer. It consists of a closed chamber (front glazing), black metallic absorber, insulation, drying chamber, trays, reflectors, and inlet/outlet openings with lids. It was designed and fabricated at the Department of Renewable Energy Sources at CTAE, Udaipur, for drying and cooking. Three plenum chambers of sizes 350 mm × 600 mm × 140 mm; 350 mm × 600 mm × 160 mm; and 350 mm × 600 mm × 50 mm are provided below the drying tray for air circulation. The chambers are also painted dull black from the outside to receive solar insolation. Three perforated wire mesh trays of size 560 mm × 290 mm are provided for supporting the material to be dried. The inlet–outlet openings are provided with lids for airflow, which can be opened and closed according to need. Food products are kept in the trays for drying and air circulation is maintained by the openings provided at the top and the bottom. Two reflectors of size 350 mm × 600 mm are hinged at either side of the box for increasing the temperature inside chamber. While using the unit as cooker, if the openings are closed with the help of lids and the whole device becomes airtight. In this condition, the food products kept in the container inside the chamber can be easily cooked. Castor wheels are provided for the easy movement of the unit. It is installed facing the south direction with an inclination of 40 °C from the horizontal.



Result and discussion

The multipurpose cook stove was tested extensively as dryer and cooker by measuring the stagnation air temperature in the chamber. The performance rating of the solar cooker was carried out in accordance with IS 13429(part3):1992 (2). Corresponding figures of merit Figure 1 and 2 with and without heat-up conditions were also measured.

The solar hotbox was also tested for drying of rewetted maize. Drying of rewetted grains is required for removing their husks to make various products in rural areas. The time required to dry up to certain moisture content level was also measured. The stagnation temperature in multipurpose cook stove is more when the side reflector is used for both drying as well as cooking.

The results of the experiment carried out on drying and cooking of food materials are presented in Tables 1 to 3.

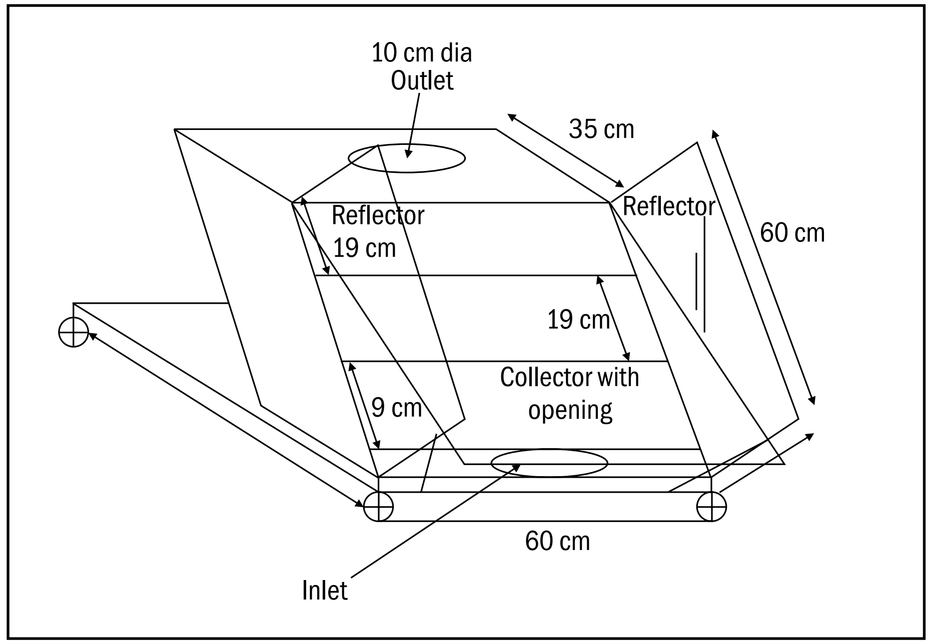


Diagram of a multi-purpose solar oven

Solar insolation

The solar insolation recorded during drying process is shown in Table 1. The solar insolation ranged from a minimum of 220 W/m^2 to a maximum of 723 W/m^2. The maximum solar insolation of 723 W/m^2 was recorded at 1p.m. of the day. This is due to higher incidence of solar radiation at noon.

Table 1 Thermal performance of drying unit in solar oven without reflector during winter in no load condition

Time (hrs)	Ambient temperature (°C)	Lower tray temperature (°C)	Middle tray temperature (°C)	Upper tray temperature (°C)	Outlet temperature (°C)	Insolation (W/m²)
10:00	25	35.33	33	35	32	534
10:30	25.33	44.43	46	42	45	582
11:00	25.66	47.66	52.66	56	54.66	622.6
11:30	26.66	48.5	54.33	56.66	56.66	626.66
12:00	28	49.33	55.33	57	54.33	656.33
12:30	29	49.80	57.33	57.66	54.66	709.66
13:00	29.33	48.66	57	57.33	55	722.66
13:30	29.66	47	56	57.33	57.33	716.3
14:00	30.33	48	55.66	58	56.33	655
14:30	30. 66	48	54.66	58	54.66	617
15:00	29.66	46	53	57	52	586
15:30	29.66	43.66	47.66	53.66	50	529.33
16:00	29.33	37	45.66	49.66	47.33	427.33
16:30	28	33.66	41.66	43.66	42.33	319.33
17:00	26.66	31	33.33	33.66	30.66	220

Drying temperature

The ambient temperature and the temperature recorded inside the multi-rack hot box at three tray levels are presented in Table 2. The ambient temperature during drying period varied from a minimum of 25–33.66 °C to a maximum of 33.5 °C, and the corresponding temperatures attended inside the solar oven were to 35 °C and 58 °C respectively. The maximum temperature of 58 °C was recorded at 2 p.m. of the day at the level of tray 2; the temperature of 31 °C at the bottom tray was the lowest, though it tended to increase in upper trays. The maximum temperature of 58 °C was obtained in the uppermost tray.

Table 2 Drying of maize in solar oven in winter

Time	Lower MC	Middle MC (w.b.)	Upper MC (w.b.)
0	33.98	33.98	33.98
60	20.21	20.85	21
120	14.72	15.1	15.45
180	11.24	11.75	12.2
240	9.26	9.9	10.02
300	7.24	7.55	7.69
360	7.14	7.32	7.41
420	7.06	7.14	7.2

Cooking Temperature

The increase in the stagnation temperature with reflector in cook stove is shown in Table 1. The increase in stagnation temperatures without mirror reflector in solar hot box is shown in Table 3. The maximum stagnation temperatures in multi-rack solar hot box may be due to appropriate insulation thickness and heat tightness of the cover plate. The calculated value of figure of merit (F1) in solar hot box is 0.119. The trend of increase in water temperature in hot box is given in Table 4. The time duration for raising water temperature from 60 °C to 90 °C in the hot box is 120 minutes. Cooking trials have also been conducted—0.5 kg of rice in 1 litre of water and 0.250 kg of split green gram (washed) was cooked in one and a half hours in winter and about one hour in summer.

Table 3 Thermal performance in MCS for cooker with reflector for figure of merit F_1 in winter

Time (hrs)	Ambient temperature (°C)	Temperature inside the cookstove (°C)	Insolation (W/m²)
10:00	26.25	42.50	518.25
10:30	26.25	63.50	601.00
11:00	26.75	96.00	637.25
11:30	27.50	114.00	668.75
12:00	28.25	115.50	696.25
12:30	29.00	117.00	721.50
13:00	29.75	119.00	741.75
13:30	30.25	113.50	727.50
14:00	30.50	107.75	691.25
14:30	30.75	103.50	662.75
15:00	29.75	98.50	613.00
15:30	29.50	93.25	538.50
16:00	29.00	79.00	470.25
16:30	28.25	74.25	361.25
17:00	27.25	50.50	177.75

Value of F1 = 0.119

Table 4 Water heating test with reflector for fig of merit F_2 in winter

Time (hrs)	Ambient temperature (°C)	Water temperature inside the cookstove (°C)	Insolation (W/m²)
10:00	24.5	45	508
10:30	24.5	50.5	568
11:00	25.5	61	621.5
11:30	26.5	77	661.5
12:00	27.5	82.5	673
12:30	28.5	87	735
13:00	29	90.5	745.5
13:30	29.5	92.25	712.5
14:00	29.5	92.5	654.5
14:30	29.6	93.25	595.5
15:00	28.7	91.5	580

Value of F_2 = 0.32

Table 5 Energy saving and payback period of MCS

Type of fuel	Calorific value (MJ/kg)	Efficiency (%)	cost (Rs)	Payback period (Years)
Firewood	19.89	20%	3.0/kg	1.86
Coal	27.21	20%	5/kg	1.52
Kerosene	45.55	40%	10/kg	2.56
Electricity	3.60 per kWh	80%	3/kg	1.3

The performance of hot box was observed throughout the year for stagnation temperature and water temperature. The maximum temperatures achieved are given in Table 4. The maximum stagnation temperature of 119 °C and water temperature of 93.25 °C were obtained in month of March.

Energy conservation and pay back period

By analysing the duration of bright sunshine hours, it has been estimated that cook stove is capable of drying and cooking for about 280 days in a year at Udaipur.

The energy required for cooking and drying is about 2.3 MJ of fuel equivalent per meal and drying. Multipurpose cook stove is capable of drying and cooking for about six persons, and it will save 50% of fuel per time. Therefore, it saves 1.15 MJ of energy per meal. Accordingly, energy saving per year was calculated and its pay back period was estimated without considering interest, maintenance, and so on.

Conclusion

The performance of multipurpose cook stove was comparable with a commercial fuel used for cooking and drying operations. The relatively short pay back period (1.3 to 2.6 years) shows that it is economical.

Acknowledgement

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