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SOLAR HOT BOX FOR COOKING AND POTATO CHIPS DRYING

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Abstract: Solar hot box was design and developed to meet the necessities of cooking, drying for domestic purpose. The device was designed to perform more than one function with increase the efficiency and reliability without reducing the quality of product and polluting environment. Solar hot box principally worked on bottom and top lids of device. When these lids were in open, it worked as solar dryer and when it closed, it worked as solar cooker. While testing the hot box as solar cooker, thermal performance factor (Figure of merit) F_1, F_2 values were found as 0.12, 0.32 for winter. The cooker with reflectors took minimum time for cooking rice, *tur* (Pigeon pea) *dal* and *mung* (Green gram) *dal.* These times were 90 min, 130 min. and 100 min. in winter. The efficiency for drying commodities as potato in solar dryer was 15.55%, in winter. The total cost of solar hot box was worked out to be Rs 2715 /-

Keywords: Solar cooking, solar drying, efficiency, economic.

INTRODUCTION

Various domestic solar appliances are developed to cater the needs of rural as well as urban population. This solar hot box consisted of drying chamber, tray, frame, inlet-outlet openings and reflectors. The specifications of the oven are illustrated in Fig. 1. It was fabricated by using GI sheet of size 350 mm x 600 mm x 600 mm and M.S. angle frame, which supported the drying chamber. The drying trays were 350 mm x 600 mm with 3-plenum chambers for air circulation had 160 mm, 140 mm and 50 mm clearance. The chambers were painted dull black from outside for better absorption of solar insolation. Three wire mesh trays of 560 mm x 290 mm size were provided for supporting the material to be dried. The inlet-outlet openings, which could be opened and closed with lids according to need, were provided for airflow. Air circulation, was allowed through the openings while using the device as a solar dryer (Siaka and Nkembo 2004). When the openings were closed, the device became airtight and for use as a cooker(Jagadeesh 2003). Two reflectors of size 350 mm x 600 mm

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were hinged at either side of the box for collecting more insolation to increase the temperature inside the chamber. The cost of device was Rs 2715 /-.

MATERIALS AND METHODS

The solar hot box was tested ( ) with household commodities like potato for drying and mug dal, tur dal, and rice for cooking for one month in winter seasons. Moisture content, drying rate and drying efficiency were calculated (Brenidorfer 1995) and while using it as a cooker, F_1 and F_2 values were calculated for the performance evaluation of the device (Chaudhari1998).

Determination of moisture content

$$\text{Moisture content \% (w.b.)} = \frac{W_1 - W_2}{W_1} \times 100$$ (Ranganna, 1986).

Where,

W_1 = Weight of sample before drying, gm, W_2 = Weight of bone dry sample, gm

Drying rate

$$Drying\ rate = \frac{\text{Amount of moisture removed (dry basis)}}{\text{Time required (hr) x (amount of dry matter)}} \times 100$$

(Chakraborty and De, 1981)

Drying efficiency (η_d)

$$\eta_d = \frac{w.\ddot{A}H_1}{Ic.Ac} \times 100$$ (Brenidorfer et. al. 1985)

Where,

w = Mass of moisture evaporated (kg) in time 't', ΔH_1 = Latent heat of evaporation (kJ/Kg), I_c = Insolation on collector surface, (kW/m^2), A_c = Collector area, m^2

Thermal performance test under stagnation temperature condition:

During no load condition the solar cooker was placed on the open ground under the sun without any raw material/food in it. Air temperature inside the solar cooker as well as ambient temperature was recorded at every half hour interval starting from 9:00 AM to 5:00 PM. The readings were taken with reflector or by covering the reflector of the solar cooker with a black cloth. When the cooker temperature reached at steady state, the final inside cooker temperature (T_{px}) and the corresponding outside ambient air temperature (T_{ax}) along with the solar radiation at the time (G_s) were noted.

Now F_1which is defined as the ratio of optical efficiency to heat loss coefficient was calculated as follows:

$$F_1 = \frac{\alpha}{U_L} = \frac{T_{px} - T_{ax}}{G_s}$$

Where,

t = Transmission of glass., α = Absorbitivity of cooking tray, U_L = Heat loss coefficient of the cooker, G_s = Solar radiation during steady state.

Thermal performance test under heat up condition

$$F_2 = \frac{F_1 (MC) w}{A (t_2 - t_1)} \log e \; 1 - \frac{(Tw_1 - T_a)}{F_1 G} \Big/ 1 - \frac{(Tw_1 - T_a)}{F_1 G}$$

Where,

F_1 = First figure of merit from stagnation test., $(MC)_W$ = Product of mass of water and specific heat in J/ ^{0} C., A = Aperture area of the cooker of cover plate in m^2.,

$(t_2 - t_1)$ = Time taken for heating from T_{w1} and T_{w2} in seconds., T_a = Average air temperature over time period $(t_2 – t_1)$ in ^{0}C., G = Average radiation over time period $(t_2 – t_1)$ in W/m^2.

RESULT AND DISCUSSION

No load testing. In solar cookers the average maximum temperature attained with reflector was 113 ^{0}C in winter. Solar cooker with reflector achieved 35 to 40 percent more temperature as compared to without reflector. The value of first figure of merit for a winter seasons for cooker with reflectors was worked out to be 0.12. Therefore, it can be said that the cooker with reflectors can be used for cooking in winter months.

Full load testing. The calculations revealed that the value of F2 for cooker was 0.32 for winter. The cooker with reflectors took minimum time for cooking rice, *tur* (Pigeon pea) *dal* and *mung* (Green gram) *dal.* These times were 90 min, 130 min. and 100 min. in winter.

Solar dryer operation

Moisture content

The drying unit in solar hot box device was tested with potato. The moisture contents of potato, determined by oven drying method were found to be 77.5, percent (w.b.) for winter and 78, percent (w.b.) for summer respectively.

No load testing.

The no load testing of dryer for solar hot box device was made to calculate the performance of solar dryer in two sets of experiments i.e. without reflector and with reflector of different food materials. The average maximum temperature attained inside the dryer without reflectors was 59.7^0C at 12:30 hrs at the upper tray (Anwar and Tiwari 2001) while the minimum was 31^0C at 17:00 hrs at the lower tray in the month of November (Fig. 2). There was 6.6 % more temperature in the dryer with reflectors than in the dryer without reflectors.

Full load testing.

In full load testing potato chips were placed in solar dryer separately. In the testing of dryer without reflector, drying was made during full load condition for the winter and summer season respectively Drying was continued till the moisture content of the potato chips tended to be minimum value. Dryer with reflector was not used because optimum temperature for drying was obtained without the use of reflector.

The data on drying of potato chips is presented in Table 1. The initial moisture content of potato was 77.5 % (w.b.). The time required drying potato chips on trays upto 6.92 moisture content (w.b.) was four days in December 03. It was observed that the reduction in moisture content was high at the beginning and reduced gradually with drying time. Fig.4.8 shows the relationship between moisture content and drying time. The drying rate was very high initially but decreased gradually with reduction in moisture content. The maximum drying rate was observed to be 0.41 gm/min/100gm of dry matter on lower tray and minimum drying rate was 0.19 gm/min/100gm of dry matter on middle and upper tray and middle tray. The related data between drying rate and moisture content was shown in Table 1. It was observed that the drying rate reduced with moisture content.

For the month of April-04 observations are given in Fig.3. The initial moisture content of potato was 78 % (w.b.). The time required drying potato chips on trays upto 5.8 moisture content (w.b.) was three days. It was observed that the reduction in moisture content was high at the beginning and reduced gradually with drying time. Fig.3 shows the relationship between moisture content and drying time. The drying rate was very high initially but decreased gradually with reduction in moisture content. The maximum drying rate was observed to be 0.41 gm/min/100gm of dry matter on lower tray and minimum drying rate was 0.26 gm/min/100gm of dry matter on middle and upper tray. The relationship between drying rate and moisture content was shown in Fig4. It was observed that the drying rate reduced with moisture content.

Drying efficiency

The observed drying efficiency of solar dryer cum cooker was 10.60 for winter and 10.16 %, for summer. Drying efficiency was high in winter than summer due to higher solar insolation in the month of April.

The second figure of merit F_2

For good performance of solar cooker it was important that there must be a good heat transfer to the cooking pots and its contents. The second figure of merit F2 was high, i.e. whether there was a good heat transfer to the contents in the pot. The values of F2 calculated for cooker with reflector was found as 0.32 and 0.30 for winter and summer respectively.

Estimating the Cost

Therefore for obtaining daily output from solar hot box device approximately 3.81 kWh of electricity was required. Electricity unit charges were Rs. 3.00, therefore in present context the cost of unit equivalent of electrical backup would be Rs. 11.43.Hence per day saving of SDC would be Rs.11.43. Based on this calculation payback period analysis of SDC was calculated. It was observed that for solar hot box device the costs could be recovered within the period of 1.1 year.

CONCLUSIONS

(1)Time required for cooking of rice, tur dal, mug dal was 90, 130 and 100 minutes in winter and 60, 90 and 75 minutes in summer. (2) Solar dryer unit of solar hot box device the efficiency in drying of Potato was found to be 10.42 % in winter where as in summer it was 10.16 % respectively. (3)Potato dried from 77.5 % to and 6.9 % in four days in winter and in they were dried from 78 % to 6.8 % in three days respectively.

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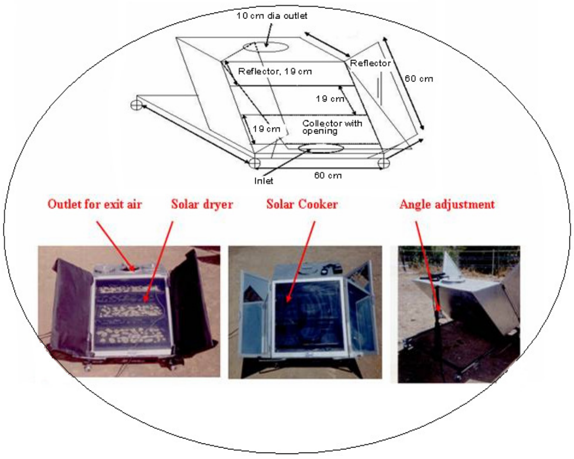
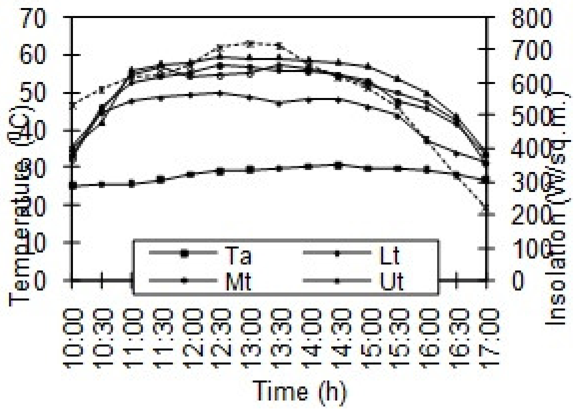


Fig. 1. Isometric view of solar hot box.



Ta: Ambient temperature, Lt, Ut, Tout: Lower tray, Upper tray and Outlet temperature, Ih- Solar insolation.

Fig. 2. Thermal performance curve for dryer without reflectors during winter.

Table-1 Drying of potato chips in solar hot box device in winter

	Lower tray		Middle tray		Upper tray	
Time (min.)	M.C. (w.b.) in %	Drying Rate gm/min/100 g dry matter	M.C. (w.b.) in %	Drying Rate gm/min/100 g dry matter	M.C. (w.b.) in %	Drying Rate gm/min/100 g dry matter
0	77.5	0	77.5	0	77.5	0
420	39	0.41	40.9	0.39	42.4	0.39
840	17.8	0.32	18.8	0.31	19.9	0.31
1260	10.6	0.24	11.3	0.23	12	0.23
1680	6.3	0.19	6.7	0.19	6.9	0.19

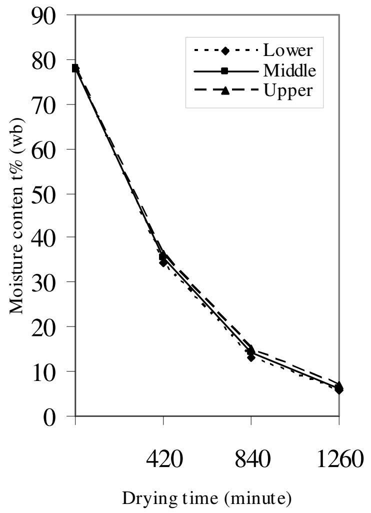


Fig. 3. Effect of drying time on moisture content of potato in summer

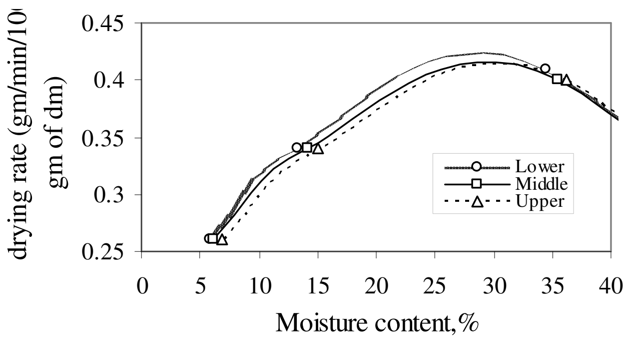


Fig. 4 Relation between moisture content and drying rate for potato in summer