DESIGN AND PERFORMANCE EVALUATION OF DIRECT MODE SOLAR DRYER

CHENDAKE A. D¹, PATIL S. B², MANE S. S³, ANUSE P. A⁴, GHADGES. B⁵, NALAWADE R. T⁶ & SHETE A. A⁷

¹Department. of Renewable Energy Sources, Dr. D. Y. Patil College of Agricultural Engineering and Technology, Kolhapur, Maharashtra, India
²Department. of Farm Machinery and Power, Dr. D. Y. Patil College of Agricultural Engineering and Technology, Kolhapur, Maharashtra, India
³, ⁴, ⁵, ⁶, ⁷ Department. of Renewable Energy Sources, Dr. D. Y. Patil College of Agricultural Engineering and Technology, Kolhapur, Maharashtra, India

ABSTRACT

Now a day, drying becomes one of the important post harvest operation for fruits, to increase shelf life. Sun drying is one of the oldest, but the cheapest and widely used methods. So the Direct Mode Solar Dryer is constructed and investigated experimentally, for the drying efficiency at a geographic location of Talsande, in the city of Kolhapur. The highest daily solar radiation, obtained at 12:00 p.m. was 857 W/m². The highest ambient temperature was obtained at 12:00 p.m. i.e., 39.8°C as well as the highest inside temperature was obtained at 13:30 p.m. & 14:30 pm i.e., 74.5°C. The maximum temperature difference ΔT was observed, i.e., 40.5°C at 14:00 p.m. The time required to dry sapota from moisture content i.e., 52.38% to 2.22% is 9 hrs. The maximum efficiency of the dryer was obtained at 61.61%, for drying of sapota.

KEYWORDS: Direct Mode Solar Dryer, Drying, Ambient Temperature, Dryer Efficiency, Sapota etc

INTRODUCTION

Sun is abundantly and naturally available on earth. We are not using the energy which we get from the sun. Drying is one of the important net not only farmer, but also for other small industries. Because drying, increasing the shelf life and adding value to the product (Biplab Paul, 2013). Solar dryers are devices that use solar energy, to dry substances, especially food. In these systems, the solar drying is assisted by the movement of the air (wind) that removes the saturated air, away from the items being dried. More recently, complex drying racks and solar tents were constructed as solar dryers. The solar dryer absorbs heat energy, to dry substances. New technologies changes techniques, but at present the increasing demand for healthy, low cost natural foods and the need for sustainable income are, bringing solar drying to the fore, as a useful alternative for surplus products. The dried product improves family's nutrition because; fruits and vegetables contain high quality vitamins, minerals and fibers. It improves the bargaining position of farmers. Sometimes farmers sell at very low prices, during the harvest season because; they cannot store or preserve their surplus products.

MATERIALS AND METHODS

Experimental Location

Talsande has a diverse climate. It is exceptionally hot and dry during summer, with temperature reaching as high as 40°C. Talsande receives about 1140 mm rainfall during monsoon.
The experiment was conducted in the year of 2015-16.

**Details about Raw Material**

Sapota fruits were selected for drying. Initial moisture content of Sapota ranged from 57 to 60 (%Wb).

**Design of Dryer**

The design of this dryer was based on thermal performance of the dryer. The box of dryer consisted of a rectangular box, made of wood with an open top. The wood was acting as an insulator. A 5mm window glass covered top of the box and edges, was coated with rubber got. This facilitates the opening and closing of the glass, for access into the box. Figure 1 and Figure 2 shows the dimensions and construction details of the dryer. The physical parameters of the dryer are illustrated in Table 1.

**Table 1: Physical Parameters of the Dryer**

<table>
<thead>
<tr>
<th>Type of Dryer</th>
<th>Direct Solar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall size – length × width (mm)</td>
<td>900 × 600</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>300</td>
</tr>
<tr>
<td>Loading (tray) area (mm²)</td>
<td>108000</td>
</tr>
<tr>
<td>Air inlet/outlet areas</td>
<td>For inlet - 4.90 cm² each</td>
</tr>
<tr>
<td></td>
<td>For outlet – 0.19 cm² each</td>
</tr>
<tr>
<td>Box material</td>
<td>Ply Wood 10 mm</td>
</tr>
<tr>
<td>Tray materials</td>
<td>Wood and aluminium wire mesh</td>
</tr>
<tr>
<td>Glazing</td>
<td>5 mm window glass</td>
</tr>
<tr>
<td>Gap: Tray surface-Cover glass (cm)</td>
<td>5</td>
</tr>
<tr>
<td>Gap: Tray surface - Dryer bottom surface (cm)</td>
<td>6</td>
</tr>
</tbody>
</table>

The dryer has three trays inside the box, for loading the product to be dried. The trays were made of aluminium wire mesh and wood. The critical parameters set inside in the dryer box, are shown in the last two rows of Table 1. The distance between the tray surface, cover glass and dryer bottom surface has kept such that, air flows both above and below the tray, for maximum drying effect.

![Figure 1: View of Direct Mode Solar Dryer](image-url)
COMPONENTS OF DRYER

Wooden box

Generally it provides rigidity to dryer, but technically it provides thermal resistance to the heat transfer, that takes place in the system, to the surrounding. So it was made from the material which has low thermal conductivity. The thickness of the side wall is 10 mm.

Top glass opening

It is opening doors, for placing food inside the dryer, and it is the passageway for the solar radiation to enter the box. We were using 5 mm window glass.

Tray

Tray act as the place in the dryer, on which product was placed. The clearance between the bottom and tray were provided, for the circulation of air. The tray’s size is 580 × 250 mm.

Insulation

Rubber insulation was provided to minimize the loss of heat from the box to the surroundings.

Stand

Stand was used to give support and for giving proper inclination to the box. It was made from angle iron.

FORMULAE USED

Moisture Content (%db)

The moisture contains of the slice of sapota, will be calculated on dry basis using formula (Seema Kumari, 2013).
M = \frac{W_M}{W_d} \times 100

Where,

M = Moisture Content (\% db),
W_M = Weight of moisture, g
W_d = Weight of bone dry matter, g

Moisture Content (\% Wb)

The moisture contain of the slice of sapota will be calculated on dry basis using formula (Seema Kumari, 2013)

M = \frac{W_M}{W_s} \times 100

Where,

M = Moisture Content (\% Wb)
W_M = Weight of moisture, g
W_s = Weight of sample, g

3.9.5 Dryer, Efficiency

\eta_c = \frac{Q_u}{A_c \Delta t}

Where,

Q_u = mc_p \Delta t,
A_c = is the collector surface area. m^2

\eta_k = \frac{M_e L_s}{A_c \Delta t}

Where,

M_e = Moisture evaporated, Kg
L_s = Sensible heat of evaporation of water at drying temperature
T = Drying time, s

\eta_d = \frac{\eta_c}{\eta_k}

RESULTS AND DISCUSSIONS

The dryer was tested with Sapota as a product. 900 grams of Sparta were loaded in the dryer.
Table 2: Observation Table of Parameters

<table>
<thead>
<tr>
<th>Time (hr)</th>
<th>Outside Temperature (°C)</th>
<th>Inside Temperature (°C)</th>
<th>Solar Radiation (W/m²)</th>
<th>Wind Velocity (m/s)</th>
<th>Relative Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:00</td>
<td>23</td>
<td>23</td>
<td>55</td>
<td>0.26</td>
<td>40</td>
</tr>
<tr>
<td>08:30</td>
<td>25</td>
<td>26</td>
<td>60</td>
<td>0.23</td>
<td>30</td>
</tr>
<tr>
<td>09:00</td>
<td>25.7</td>
<td>42.5</td>
<td>170</td>
<td>0.36</td>
<td>20</td>
</tr>
<tr>
<td>09:30</td>
<td>26.5</td>
<td>50</td>
<td>375</td>
<td>1.32</td>
<td>20</td>
</tr>
<tr>
<td>10:00</td>
<td>28</td>
<td>60</td>
<td>534</td>
<td>1.15</td>
<td>20</td>
</tr>
<tr>
<td>10:30</td>
<td>30.1</td>
<td>63</td>
<td>700</td>
<td>1.47</td>
<td>20</td>
</tr>
<tr>
<td>11:00</td>
<td>30.6</td>
<td>66</td>
<td>762</td>
<td>3.40</td>
<td>20</td>
</tr>
<tr>
<td>11:30</td>
<td>37.5</td>
<td>70.5</td>
<td>825</td>
<td>3.00</td>
<td>20</td>
</tr>
<tr>
<td>12:00</td>
<td>39.8</td>
<td>71.5</td>
<td>857</td>
<td>2.30</td>
<td>20</td>
</tr>
<tr>
<td>12:30</td>
<td>36.4</td>
<td>73</td>
<td>780</td>
<td>1.80</td>
<td>20</td>
</tr>
<tr>
<td>13:00</td>
<td>35.3</td>
<td>73.5</td>
<td>740</td>
<td>1.74</td>
<td>20</td>
</tr>
<tr>
<td>13:30</td>
<td>35.8</td>
<td>74.5</td>
<td>703</td>
<td>1.83</td>
<td>20</td>
</tr>
<tr>
<td>14:00</td>
<td>34</td>
<td>74.5</td>
<td>610</td>
<td>0.60</td>
<td>20</td>
</tr>
<tr>
<td>14:30</td>
<td>34.3</td>
<td>72.5</td>
<td>591</td>
<td>5.00</td>
<td>20</td>
</tr>
<tr>
<td>15:00</td>
<td>33.7</td>
<td>70.5</td>
<td>531</td>
<td>3.86</td>
<td>20</td>
</tr>
<tr>
<td>15:30</td>
<td>33.4</td>
<td>64.5</td>
<td>388</td>
<td>2.30</td>
<td>20</td>
</tr>
<tr>
<td>16:00</td>
<td>32.7</td>
<td>59.5</td>
<td>141</td>
<td>1.45</td>
<td>20</td>
</tr>
<tr>
<td>16:30</td>
<td>31.5</td>
<td>52</td>
<td>102</td>
<td>2.30</td>
<td>20</td>
</tr>
<tr>
<td>17:00</td>
<td>29</td>
<td>49</td>
<td>65</td>
<td>0.82</td>
<td>20</td>
</tr>
</tbody>
</table>

 TableRow 2 Contd.

<table>
<thead>
<tr>
<th>Time (hr)</th>
<th>Outside Temperature (°C)</th>
<th>Inside Temperature (°C)</th>
<th>Solar Radiation (W/m²)</th>
<th>Wind Velocity (m/s)</th>
<th>Relative Humidity (%)</th>
</tr>
</thead>
</table>

TEMPERATURE PROFILE

Variation of Outside Temperature with Time

As per Figure 2 the maximum temperature attained is 39.8 °C at 12:00 pm and minimum temperature is 23 °C at 08:00 am.
Variance of Inside Temperature with Time

As per the figure 3, the maximum temperature attained is 74.5°C at 13:00 pm and 14:30 pm and minimum temperature is 23°C at 08:00 am.

Variation of Solar Radiation with Time

As per figure 4, the maximum solar radiation attained is 857 W/m² at 12:00 pm and minimum solar radiation is 55 W/m² at 08:00 am.

MOISTURE CONTENT

The initial moisture content of sapota was 52 per cent and final moisture content after drying was obtained as 2.22 per cent.

DRYING EFFICIENCY

The drying efficiency that was obtained from the observation is 61.61%. The drying time required to dry sapota is 9 hrs.

\[ \eta_d = \frac{W_0}{W_f} \times 100 \]
\[
\eta_d = \frac{0.3755}{0.6094} \times 100
\]

\[\eta_d = 61.61\%\]

CONCLUSIONS

The maximum temperature attained inside the dryer is 74.5 °C, at 13:30 pm and 14:30 pm and minimum is 23 °C at 08:00 am. The time required to dry sapota from 52% moisture content to 2.22% moisture content in direct mode solar dryer is 9 hrs. The maximum solar radiation attained is 857 W/m² at 12:00 pm. The efficiency of the dryer has been obtained as 61.61%.

REFERENCES
