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Development of Solar Dryer for UV Sensitive Arid Area Medicinal Plants

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Abstract: Deserts and arid areas in India lack energy sources and specialized transportation facility. One of the main reasons is sparse population and low production density. Since most of them are of perishable nature, they are consumed mostly locally and has hardly any economic value as compared to the cost of production. Consequently, people in these areas are loosing their interest in these medicinal plants and fruits mainly. With continued migration of people to other areas, the danger of extinction of these plant species is also looming large. Introduction of alternative means of sustainable development is vital for deserts and arid area development and ecosystem preservation. Solar drying has immense potential to initiate the reversal of the present situation. In the present paper, family size (5 kg capacity) UV sensitive FRP solar dryer is designed for drying of low thickness drying materials including leaves. The performance is modeled theoretically and evaluated experimentally using shrinkage factor. It was found that the heat transfer coefficient remains constant for thickness of drying materials between 2 mm and 10 mm, while it has hardly any effect on less than 2 mm materials, especially leaf types. The heat transfer coefficient is controlled by the combination of high heat capacity material and Phase change material to preserve the colour of the drying material.

Key Words: Arid, Medicinal plant, Solar dryer, UV protection

1. Introduction

Arid areas and deserts all over the world has inherent drawback - low population density. With globalization of economy, profit making has become the keyword. Almost all the governments are stressing on privatization. These developments have caused considerable negligence in developmental efforts in arid and desert areas. In India, with Information Technology revolution, things are slowly changing in arid areas with private initiatives, still a long way is left ahead. Nevertheless, in last decade, climate related disasters, mostly attributed to green house gas emissions have decisively influenced our perception of deserts and arid areas. Material and human loss due to these disasters all over the world has compelled planners and researchers to find ways of remedy and alternative methods of development. It is felt that environmental degradation affects events beyond political boundaries. International Energy Agency under its Annexure 8 brought together scientists and researcher to investigate 'Very Large Scale Photo Voltaic' (VLS plants to temperature and direct sunrays, particularly Ultra Violet rays makes the existing designs unsuitable. Though UV- opaque glasses are available in cities, but these are costly and the cost itself renders it infeasible for the present purpose. Family cabinet solar dryer (CSD) is designed, fabricated of Fibre Reinforced Plastic (FRP) and investigated. It can use diffused sunlight and indirect heating for drying. Theoretical modelling and field investigation of the process shows that controlling the heat transfer coefficient by a combination of H PV) installation in deserts, for future energy supply. European commission, US and Japan also formed task group for assessing such options.

At the same time, another group of researchers initiated investigation into carbon mitigation option by plantation in desert and arid areas. Large scale plantation remains still the best option for creating carbon stock. Besides, it helps in reclaiming land in several areas for agriculture purpose, needed to feed burgeoning population in coming years. These efforts were also supplemented by peripheral investigation into other aspects of arid areas and deserts such as, preservation of its ecology, better livelihood for native people, desert plants and fruits etc. Alternative methods of development and exploration of untapped medicinal properties of desert and arid area plants attracted several researchers from various disciplines.

Arid areas adjoining Thar Desert in North-West India is also a rich source of medicinal plants and fruits. These were used to be traditionally grown by local people in sustainable manner, taking into account local requirement, production capacity of soil and, scarce natural resources such as water availability. These considerations have resulted into scattered plantation pattern throughout the region. These medicinal plants are mostly consumed locally due to perishable nature, scattered plantation, unavailability of technical expertise and means to preserve and transport to nearby markets. These arid areas are also worst hit by global climate changes.

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Options of sustainable development have shrieked at a faster pace than expected. Ecosystems are under stress and regional disparity in economic development has tremendously increased, causing demographic changes.

These arid areas are blessed with high solar insolation almost throughout the year. Solar dryers can be used for drying and preservation of these medicinal plants (Choudhary *et al*., 2005, 2006, 2009). However, sensitivity of these igh Heat Capacity material and phase change material, improves the quality of the dried product. Phase change materials for such uses are investigated by Sharma *et al*. (2004) and are also documented by Grigoriev and Meilikhov (1995). It is very crucial for drying object of thickness 2-10 mm.

2. Materials and Methods

2.1. Theoretical modelling

In order to derive expression for heat transfer coefficient 'h' (W/m^2 °C), the following assumptions are made to simplify the model,

(i) Evaporation occurs only at the surface of the drying mass,
(ii) Within the drying mass, temperature and moisture content remains almost uniform within the solid. This is true since only thin materials are considered for drying. This also emplies that there is no temperature gradient in drying mass. This is justified since the ratio of internal to external resistance to heat transfer, (Bi = hL/k) (Biot number, Bi) remained less than 1.
(iii) The convective heat transfer remains the dominant mode of heat transfer.

The heat balance equation for the drying mass can be written as (following Luikov, 1968),

$$m_d\ (1+M)C_P\,\frac{dT_P}{dt} = h\,A(T-T_P) - n_w\ A\,\lambda \qquad (1)$$

where, md is mass of dry matter (kg), M is moisture content (kg water/kg dry matter), Tp is temperature of sample surface (C), T temperature of drying air (°C), A is surface area (m^2), h is heat transfer coefficient (W/m^2 °C) and, λ is latent heat of vaporization of sample (kJ/kg), Cp is specific heat capacity (kJ/kg °C), t is drying time (s).

The water mass flux, nw can be expressed in the following form,

$$n_w = \frac{m_d}{A}\frac{dM}{dt} \qquad (2)$$

Here, nw is correlated to the dried mass M. From equation (1) and (2), it follows,

$$m_d\ (1+M)C_P\,\frac{dT_P}{dt} = h\,A(T-T_P) - m_d\left(\frac{dM}{dt}\right)\lambda \qquad (3)$$

This leads to an expression for heat transfer coefficient,

$$h = \frac{\left(\frac{V}{A}\right)\rho\,C_P\ (1+M)\,\frac{dT_P}{dt} + \frac{m_d}{A}\left(\frac{dM}{dt}\right)\lambda}{(T-T_P)} \qquad (4)$$

where, ρ is density of drying material (kg/m3), V is volume of sample (m^3).

The ratio of surface area to volume (shrinkage factor) is investigated for small pieces of *Emblica officinalis*, *Aegle marmelos* for fixing the amount of high heat capacity material (HHCM) and Phase change material (PCM) in cabinet size solar dryer. Since shrinkage depends on the moisture content and the type of product, the ratio of Av and Avo is considered to be important as found earlier in case of potato drying (Ratti, 1994; Rahman and Kumar, 2009). They defined the shrinkage factor hsh as,

$$h_{sh} = \frac{A_V}{A_{VO}} = 2.175 - 3.194\left(\frac{M}{M_O}\right) + 3.661\left(\frac{M}{M_O}\right)^2 - 1.661\left(\frac{M}{M_O}\right)^3 \qquad (5)$$

Where, Avo and Av are initial and instant area per unit volume (1/m), Mo and M are initial and instant mass of the drying object (kg).

2.2 Construction of CSD

Three prototypes of family size cabinet solar dryer were constructed from (a) double layer galvanize sheet, (b) particle wooden board and, (c) Fibre Reinforced Plastic board (FRP). Later was found to be most efficient since the loss of thermal energy was minimal. **Figure 1** shows the family size FRP

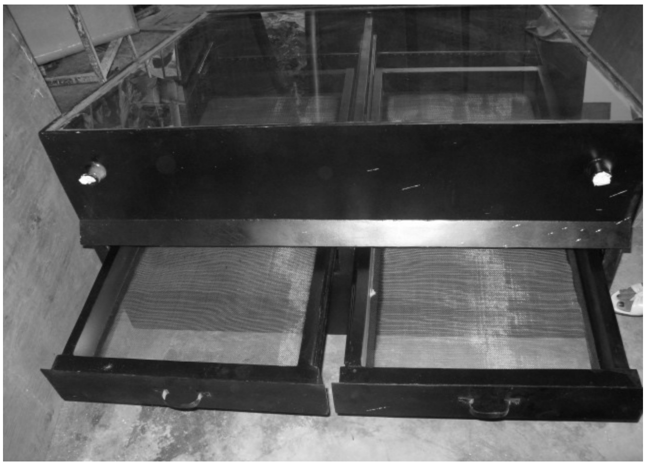

Fig. 1. Family size FRP CSD.

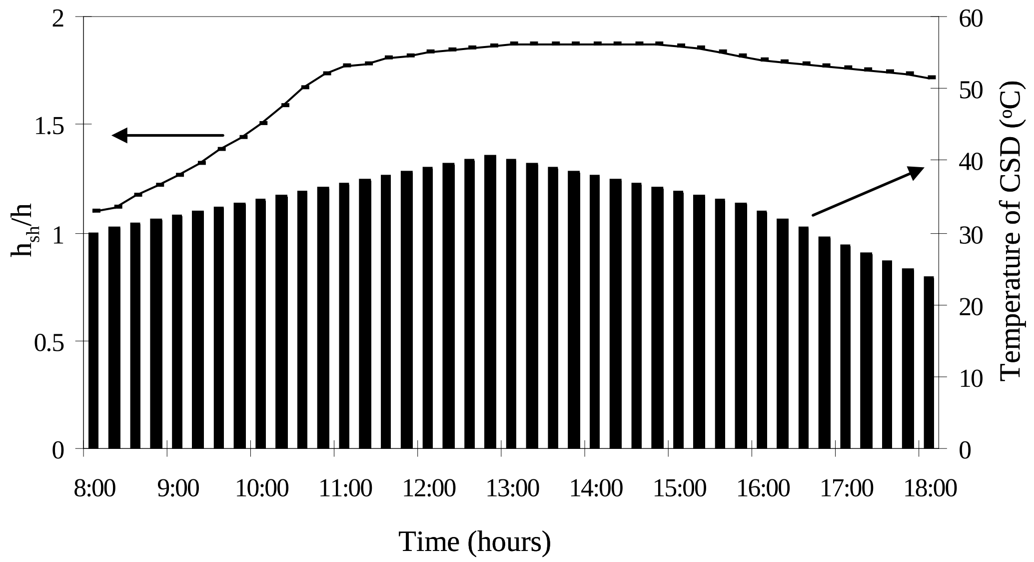

Fig. 2. Variation of temperature inside the CSD with 45 kg of HHCM and 15 kg of PCM, and corresponding variation in hsh/h.

from all the sides. In the bottom, 0.75 mm particle board is Cabinet Solar Dryer (CSD). The effective area of the CSD exposed to solar radiation is 1 m^2. It has double layer of FRP used between the two layers of FRP to provide strength for placing up to 80 kg of HHCM and PCM. In side walls, 0.75 mm of thermocole is used between the FRP layers to improve insulation. The whole system is properly insulated. It has two trays with two compartments each. On these trays, drying materials up to 5 kg may be placed for drying. At the bottom a perforated pipe is placed to suck air by the PV operated fan at the top to control temperature in a particular range. This also helps in fast removal of high moisture from CSD. Drying material in the upper trays are covered to protect it from UV rays.

Table 1. Vaiation of hsh/h with HHCM and PCM.

Thickness of Materials (mm)	PCM (kg)	HHCM (kg)	h_{sh}/h $(W/m^2\ ^oC)^{-1}$
10月8日	20	45	<1.8
8月6日	15	50	<1.8
6月4日	10	60	<1.8
4月2日	5	70	<1.8
<2	0	80	<1.8

3. Results and Discussion

At first, temperature stabilization inside the dryer was the major issue as it varied with insolation and even reached 90 degree C. It affected the quality of the dried product making it sometimes brittle. Loss of nutrients was also observed. Therefore, HHCM (blackened stones and pebbles) were used, but it delayed initial rise in temperature and reduced the number of hours suitable for single day drying. A 65 kg combination of phase change material (NaOH . H_2O) and HHCM in the ratio of 1:3 was found suitable for drying of 5 kg of medicinal plants and fruits (more than 5 mm thickness). However, two problems were detected in the course of investigation,

(a) the drying is not suitable for thin masses (less than ~ 5 mm thick) including leafy types.
(b) Drying by direct insolation caused blackened texture with breaking of sugar content if present.

Available literature showed that it is mainly due to two reasons, uncontrolled heat transfer coefficient and UV rays. Hence in the present investigation, a methodology is developed to control the heat transfer coefficient. The ratio of Shrinkage factor to heat transfer coefficient is found to be most suitable for controlled drying of medicinal plants and thin pieces of medicinal fruits. The ratio of hsh/h must be kept below the absolute value 2 for better drying results. Shrinkage factor depends upon moisture content inside the sample and the external temperature. Higher water flux at high temperature damages the texture and also affects the quality of the product. **Figure 2** shows the variation of CSD temperature and corresponding variation in hsh/h for drying of Emblica officinalis, and Aegle marmelos pieces in the FRP CSD. The ratio of HHCM and PCM affects the parameter hsh/h. It also depends upon the thickness of the drying objects. However, it has hardly any effect from the total mass of the drying material.

To cut off UV radiation, three methodologies were applied,

(a) Top glass cover was changed to UV opaque glass. Though the results were excellent, it was considered impractical to use such glasses. Their availability in arid areas and cost was major cause of concern.

Fig. 3. Drying under direct sunlight in CSD.

Fig. 4. Drying under shade in CSD.

(b) Top plane glass is changed to provide diffused light so that instead of direct sunlight, only diffused light could enter the CSD. This system reduced the efficiency by more than 30%. Hence, it was discarded.

(c) A very simple method was evolved - using black paper over the drying object supplemented by small one watt fan at the top and operated by power from PV panel. It was most effective.

Particularly in case of leafy types, it was found easy to dry under such condition. **Figure 3** shows the drying results of leaves with medicinal characteristics drying under direct sun light in the CSD. **Figure 4** shows the result of drying under shade using the above mentioned methodology. The former changed to brownish colour while the later maintained the green colour upon complete drying, i.e., less than 7% moisture content.

4. Conclusion

Solar drying of medicinal plants and fruits from arid areas has several benefits. It encourages economic activity in arid areas and provides ingredients to newly sought after 'natural cure'. By evolving methodology for cost-effective drying process for the illiterate masses, new and alternative opportunities of development could be created. It would help in stabilizing life of people in these areas and stop migration of people to stressful life in search of livelihood. The FRP CSD design developed and presented here is cost effective and operation friendly. It can be used for drying of several products in arid areas with minor changes in the ratio and amount of high heat capacity material and phase change material.

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