IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
CETCME-2017
"Cutting Edge Technological Challenges in Mechanical Engineering"
Noida Institute of Engineering & Technology (NIET), Greater Noida
Vol. 4, Special Issue 3, February 2017

Experimental Investigation of the Performance of Tubular Solar Dryer

Adit Rana[1], Ranchan Chauhan[2], Muneesh Sethi[3], Amit Kumar[4], Varun Bhola[5]

Assistant Professor, School of Mechanical and Civil Engineering, Shoolini University, Solan (HP) India [1, 2]

Professor, School of Mechanical and Civil Engineering, Shoolini University, Solan (HP) India [3]

Student, School of Mechanical and Civil Engineering, Shoolini University, Solan (HP) India[4, 5]

Abstract: This paper presents a thermodynamic performance of tubular solar dryer. Drying experiments for Himalayan fig was conducted, after a preliminary stage of the investigation which included measurements for the determination of the collector efficiency. These results showed that the warm outlet air of the collector attains temperature levels suitable for drying of agricultural products without the need of preheating. Thus, the present collector was used as the heat source for a drying chamber in the frame of the development of a novel, convective, indirect solar dryer; given the fact that in the literature there are only a few studies about this type of collectors in solar drying applications.

Keywords: Solar dryer; Thermal efficiency, Himalayan fig; Solar collector.

I. INTRODUCTION

All over the world energy plays a pivotal role in terms of overall development of any nation. Without energy, modern nations are crippled, so we cannot deny the precise involvement of energy in any form. To a large extent most of the economic activities and development of any nation is based on energy, no nation can drag on their development without energy. According to the reliable sources 15% of the world population is malnourished [1]. Due to continuous rise in world populations the major problem faced by people is imbalance of food and solution for this is to preserve food and reduce the food losses. Generally in developing countries food problems arise, due to the inability to preserve food. More than 80% of food is being produced by small farmers in developing countries [2].

These farmers dry food products by natural sun drying, an advantage being that solar energy is available free of cost, but there are several disadvantages which are responsible for degradation and poor quality of the end product. From the limited data available on post-harvest losses in fruits and vegetables, it is understood that the actual losses are much higher. The minimum reported loss is 21%, while some references indicate estimates of above 40–50% of food losses [3].
The most notable feature is that many varieties of fruits are seasonal and many of them are consumed in their dried form to a large extent which has been made possible by the process of drying. The energy requirement for agricultural products can be determined from the initial and final moisture content of each product. Different products have different drying rates and maximum allowable temperatures which have to be achieved depending upon the type of product dried.

II. DESIGN CONSIDERATIONS

In the investigation of experimental results of the present study, different mathematical formulas have been used for each idiomatic section for the purpose of investigation.

A. Calculation for the optimal solar collector area
The Sun –air temperature can be determined by using entropy balance equation as this is a new type of mixed mode solar food dryer for drying applications.

$$\Theta_{max} = 1 + \frac{GAc(\tau\alpha)}{ULTpTa} \qquad (1)$$

Where this Θ_{max} is ratio of (T_{max}/T_a) and it is also called as stagnation temperature it defines the maximum amount of temperature reached by collector.

B. Heat collection efficiency
The performance and efficiency of a solar food dryer can be determined using the equation $\eta_{th}$and thermal efficiency is defined as ratioof the useful heat energy gain to the rate of the total incident solar energy and is expressed as [4]:

$$\eta_{th} = \frac{\dot{m}\ Cp\ (To - Ti)}{I\ A_c} \qquad (2)$$

Where, m is mass of air, C_p is specific thermal capacity of air, G is incoming global solar radiations, and Acis area of collector. Additionally, another performance indicator pick up efficiency can be derived using following equation η_p:

$$\eta_p = \frac{W}{\rho \times t \times \dot{m} \times (h_{as} - h_i)} \qquad (3)$$

Where, W is the weight of water evaporated from the product, ρ is air density, t is time in seconds, ṁ is mass flow rate of air, h_{as} is relative humidity at drying chamber, h_i is relative humidity at inlet.

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
CETCME-2017
"Cutting Edge Technological Challenges in Mechanical Engineering"
Noida Institute of Engineering & Technology (NIET), Greater Noida
Vol. 4, Special Issue 3, February 2017

III. METHODOLOGY

Solar dryer with tubular aluminium pipe absorber was designed. The solar dryer is divided into three consecutive parts i.e. inlet duct, solar collector section and drying chamber as shown in Fig. 1. Solar collection duct is the air duct through which air passes and gets heated up through convection mechanism of heat transfer [5].

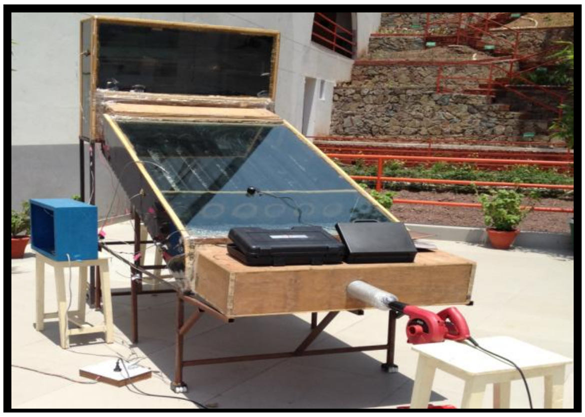

Fig. 1 Pictorial view of experimental setup of solar dryer

A. Solar collector section

The collector is fabricated from the ply-wood flumps of different cross-sections. The solar radiation collecting area of the solar collector is 1.48 m × 1 m × .22 m and collector is placed at an inclination angle of 32°. The collector is further divided into two parts: aluminium chip section and second is aluminium tubes with cast iron chips. In first section 2kg aluminium chips were spread all over the section, dimension of first section is .473 m × 1 m. In second section six aluminium pipes of length 1.007 m respectively at a distance of .20 m are placed as absorber medium under the glass. A thick layer of thermo-cole and glass-wool were placed underneath the pipes for insulation purpose. Solar energy received by the collector is maximum if the inclination angle of the collector (i) with the horizontal surface [6] is such as; $(\varphi - 10^{o}) \leq i \leq (\varphi + 10^{o})$ as shown in the Fig. 2.

B. Drying Chamber

The drying chamber is also fabricated from plywood flumps of different cross-sections. The dimension of drying chamber is .31m × 1 m × .500m. Hot air from the solar collector passes through the trays where the product is being dried. The dimension of the tray is 0.28m × 0.8m. The framework of the drying chamber is a 0.003 m thickness glass. A door is provided at the back side of the drying chamber for loading and unloading of the product and at the top section of the drying chamber air outlet vent is provided for the moist air outlet.

C. Equipment for air handling

As the solar dryer is a mixed-mode forced convection type so ambient air is blown through the inlet duct to the whole set-up by means of a centrifugal blower driven by 600 W, two phase, 220 V and 1800 rpm motor. The inlet of the inlet duct is connected by an aluminium pipe with outer diameter .82m with air tight gasket for precise control and continuous flow of air throughout the system.

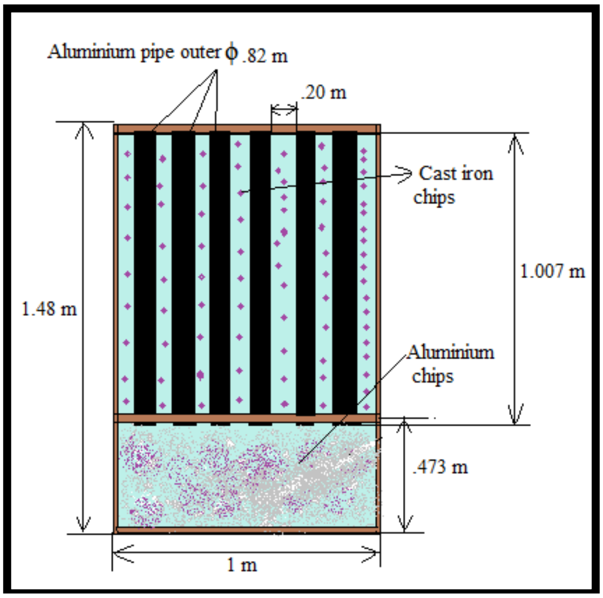

Fig. 2 Collector section of solar dryer

D. Materials and methods for product drying

Himalayan fig with pre treated 0.5% of ascorbic acid was selected for the experimentation. The samples were placed over netted trays (0.28m × 0.8m) at mid height position in the drying chamber. The initial moisture content of the sample product was determined by the hot air oven method by considering the fact of safe drying for Himalayan fig should be conducted in a range of 40-70°C.

IV. INVESTIGATION METHODOLOGY

A. Data acquisition

Ambient air temperature, temperature of air at outlet of solar collector (plenum), and solar radiation were recorded through the data acquisition system. Solar collector allows the increase in collector's mean outlet air temperature from 10° C to 21° C above the mean ambient air temperature. The value of rise in collector's mean outlet air temperature mainly depends upon the value of incoming solar radiations and air flow rates. These values agree with the range reported by the Kadam and Samuel [6].Pick-up efficiency determines the efficiency of moisture removal by the drying air from the product.

$$\eta_p = \frac{W}{\rho \times t \times \dot{m} \times (h_{as} - h_i)}$$

Where W is the weight of water evaporated from the product, ρ is air density, t is time in seconds, $\dot{m}$ is mass flow rate of air, h_{as} is relative humidity at drying chamber, h_i is relative humidity at inlet. Pick-up efficiency generally decreases with decreasing moisture content in the product.

B. System and operating parameters

The performance evaluation of solar dryers significantly influenced by following parameters:

- Drying air characteristics such as: drying air temperature, humidity and velocity of drying air.
- Product variables such as: amount of product, initial and final moisture content of product, product’s safe drying temperature range.
- Dimensional variables such as: Length of dryer, width, height of dryer, inclination angle and dryer configuration.

Performance evaluation of a solar assisted dryer considers these parameters [8]. The selection of a solar dryer defines a negotiation of product quality, dryer cost, safety consideration and convenience of installation. The list of values of system and operating parameters are given in Table 1.

V. RESULTS AND DISCUSSIONS

The Himalayan fig with pre treated 0.5% of ascorbic acid is as shown in Fig. 3. For the evaluation of performance of tubular solar food dryer, measurements were taken at different days and also for the use of any solar assisted system the most important character is to find out the amount of total global solar radiations received by the system and its distribution in the time.

Table 1: System and operating parameters

Description		Parameter	Symbol	Value/range
Physical features of dryer		Area of collector, m	A_c	1.48
Type	Integrated mixed-mode type	Thickness of collector glazing, m	t_g	0.009
		Transmittance-absorptance product	$(\tau\alpha)$	0.9
		Tray area, ,	A_{tray}	0.224
		Thickness of drying chamber glazing, m	t_{gc}	0.003
		Length of aluminium tube, m	L_{tube}	1.007
Operating parameters		Air velocity, m/s	V_a	0.70
		Solar radiation intensity, W/ m^2	I	250-950
		Ambient air temp. ^{0}C	T_a	30-37

Fig. 3 Pictorial view of Himalayan fig

This character shall estate the energy storage capacity and collector area of the system. For the use of any solar assisted system the most important character is to find out the amount of total global solar radiations received by the system and its distribution in the time. This character shall estate the energy storage capacity and collector area of the system. The incident solar radiations, ambient air temperatures and drying chamber temperatures of day first are represented by Fig. 4.

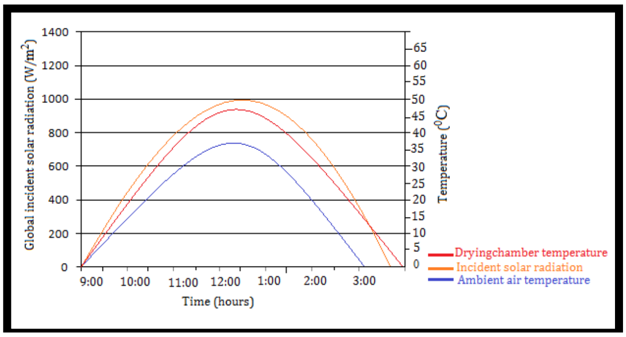

Fig. 4 Instantaneous thermal flux, drying chamber and ambient temperatures

It can be seen that the drying air temperature increase in the dryer according to incident radiation. From meteorological data available, this straight line obtained can help to estimate the outlet air temperature while designing a solar dryer. All the mass transfers vapour and liquid under effect of various temperature gradients makes the study complex. The problem becomes more complicated when it is a question of using achieved results to dimension or model of the dryer. The approach is generally experimental. It consists in the determination of two representations of curves which are the product moisture content with the time and the drying rate with the time. Pick up efficiency decrease with decreasing moisture content in the product and increasing the temperature of the drying air will increase the drying rate at a constant air velocity range from 0.3 m/s – 3 m/s, but from the drying

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
CETCME-2017
"Cutting Edge Technological Challenges in Mechanical Engineering"
Noida Institute of Engineering & Technology (NIET), Greater Noida
Vol. 4, Special Issue 3, February 2017

efficiency figures for forced convection dryers, it is difficult to find the right value of air flows with a small temperature rise or small airflow values with a high temperature rise to influence the drying process. At same incoming solar radiation levels, efficiency values for different dryers can be same at different air flow rates. Therefore by the consideration of this phenomenon it might be useful while designing a solar dryer to improve the performance of solar dryer for a specific product. In order to bring an effective drying process a temperature evaluation of at least 10- 15 ^{0}C is required. The duration of drying air temperature 10 ^{0}C above the ambient temperature generally depends on the site location of the dryer, and it is a useful indication for dryer performance.

The thermal performance of dryer using aluminium chips is found to be better than simple absorber as rise in ambient air temperature ranges from 15-25 ^{0}C which is very useful in drying process. The value of ambient relative humidity reduced from RH66% - RH16% which is also a good indication for less drying time because the ability of drying air to hold more moisture can be increased by dehumidifying the ambient air. As the value of outlet relative humidity is much below than the ambient relative humidity therefore dryer have a potential of drying product from15-20 kg. As the product is being dried is a Himalayan fig which is a temperature-sensitive product therefore temperatures in the range of 35-55 ^{0}C are recommended for drying operation. The resulted mean drying cabinet temperature is also ranged from 39-52 ^{0}C. It took 36 hours to dry the product at a level of 20% moisture content which is an acceptable result with thermal efficiency. The future perspectives of investigation of solar tubular food dryer can be concentrated over optimizing the process parameters using multi criteria decision making methodologies. The multi criteria decision making methods have been extensively used in various engineering, science and management problems [9-14] where the best alternative solution id to be sought from the existing numerous.

VI. CONCLUSIONS

1. Pick up efficiency decrease with decreasing moisture content in the product and increasing the temperature of the drying air will increase the drying rate at a constant air velocity range from 0.3 m/s – 3 m/s.
2. In order to bring an effective drying process a temperature evaluation of at least 10- 15 ^{0}C is required. The duration of drying air temperature 10 ^{0}C above the ambient temperature generally depends on the site location of the dryer, and it is a useful indication for dryer performance.
3. The thermal performance of dryer using aluminium chips is found to be better than simple absorber as rise in ambient air temperature ranges from 15-25 ^{0}C which is very useful in drying process.
4. The value of ambient relative humidity reduced from RH66% - RH16% which is also a good indication for less drying time because the ability of drying air to hold more moisture can be increased by dehumidifying the ambient air.
5. As the product is being dried is a Himalayan fig which is a temperature-sensitive product therefore temperatures in the range of 35-55 ^{0}C are recommended for drying operation. The resulted mean drying cabinet temperature is also ranged from 39-52 ^{0}C. It took 36 hours to dry the product at a level of 20% moisture content which is an acceptable result with thermal efficiency.

REFERENCES

[1] Annual report, Central Electricity Authority, Ministry of Power Government of India, 2012-2013.
[2] Energy outlook, MNRE, Government of India Ministry of New and Renewable Energy, 2013.
[3] J.A. Duffie, W.A. Beckman, Solar Engineering of Thermal processes, John Wiley and Sons, Inc. Publication, New York, Fourth Edition 2013; 223 -240.
[4] R. Chauhan, N.S. Thakur, Investigation of the thermohydraulic performance of impinging jet solar air heater, Energy, 68; 2014:255-261
[5] R. Chauhan, N.S. Thakur, Heat transfer and friction characteristics of impinging jet solar air heater, Journal of Renewable and Sustainable Energy, 4; 2012:04321-7
[6] R. Chauhan, N.S. Thakur, S. Chamoli, Optimum tilt angles for grid interactive solar photovoltaic array, Applied Mechanics and Materials, 2012; 110:4554 – 4558.
[7] D. Kadam, DVK Samuel, Convective solar flat-plate collector for drying, BiosystEng, 2006; 93: 189-98.
[8] S. Soponronnarit, M. Assayo, Performance evaluation of a solar banana dryer, International Energy Journal, 1991; 13: 30-36
[9] A. Sharma, R. Chauhan, T. Singh, A. Kumar, R. Kumar, A. Kumar,M. Sethi, Optimizing discrete V obstacle parameters using a novel Entropy-VIKOR approach in a solar air flow channel, Renewable Energy, 2017; Article in Press.
[10] R. Chauhan, T. Singh, N. Kumar, A. Patnaik, N.S. Thakur, Experimental investigation and optimization of impinging jet solar thermal collector by Taguchi method, Applied Thermal Engineering, 2017; Article in Press.
[11] T. Singh, A. Patnaik, R. Chauhan, P. Chauhan, Selection of brake friction materials using hybrid Analytical Hierarchy Process and ViseKriterijumskaOptimizacijaKompromisnoResenje Approach, Polymer Composites, DOI: 10.1002/pc
[12] T. Singh, A. Patnaik, B. Gangil, R. Chauhan,Optimization of tribo-performance of brake friction materials: Effect of nano filler, Wear, 2015; 324-325:10-16.
[13] R. Chauhan, T. Singh, N.S. Thakur, A. Patnaik, Optimization of parameters in solar thermal collector provided with impinging air jets based upon preference selection index method, Renewable Energy, 2016; 99:118-126.