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PARAMETRIC STUDY OF ROCK BED REGENERATOR FOR VEGETABLES DRYING USING COUNTER-CURRENT CONTINUOUS CONVECTIVE CONVEYOR

Anmol Prince[1], Himmat Singh[2], Vijay Singh Bisht[3] , Arjun Yadav[4]

[1] Assistant Professor, Department of M.E., Maya Institute of Technology and Management Dehradun, Uttarakhand (India)

[2,3]Assistant Professor, [4]P.G. Scholar, Department of M.E., Faculty of Technology (U.T.U.) Dehradun, Uttarakhand (India)

ABSTRACT

In this paper, moisture removal is been done with the help of continuous convective conveyor. In the continuous convective conveyor vegetables such as (potatoes slices & onions flakes) and hot air are flowing in the counter-current manner. The results from the calculations of continuous convective conveyor are compared with the open sun drying of the given vegetables. The specifications of continuous convective conveyor are not included in this study. Only calculations are performed. The mass flow rate of hot air is decided by the optimizing the parameters of rock bed during discharging cycle. And the mass flow rate is calculated by moisture balance calculation of continuous convective dryer. For charging and discharging of rock bed two critical parameters namely: rock diameter and mass flow rate of air are optimizes

Keywords: Open Sun Drying, Rock Bed, Continuous Convective Conveyor

I. INTRODUCTION

In India the greater part of the product is lost amid post harvest, because of the absence of legitimate preparing and storerooms. In India, weakening of impressive amounts of vegetables happens amid capacity operations. Different additive strategies have been utilized to minimize this misfortune. The most primitive technique utilized in protecting (onion drops and potato cuts) crumbling is that they are spread on the ground, for example, wheat raisins, figs & apricots, presented to the sun so as to be dried. This technique is regularly known as open sun drying (OSD).Similarly yields can be dried at a quicker rate in the convective transport. **Khankari et al.[1]** built up a numerical model for dampness movement considering dispersion as the essential transport system. **Smith and Sokhansanj [2]** has built up a characteristic convection warmth move show in which the thickness of air was thought to be a component of temperature and supreme mugginess. **Sokhansanj [3]** used experimental data for thin layer drying of barley to show that a model that a coupled heat and mass transfer within a single kernel of grain improves prediction of the drying rate **Miketinac et al.[4]** detailed five models simulating the process of simultaneous heat and mass transfer drying a thin layer of barley. The heat transfer coefficient was found to vary from 43 to 59 W/m^2/K depending on the form of drying model. **Sodha et al.[5]** presented a simple analytical model based on simultaneous heat and mass transfer at the product surface and included the effect of wind speed, relative humidity, product thickness and heat conducted to the ground for open sun drying and for a cabinet dryer.

II.SYSTEM MODEL

Storage in rock bed is accomplished by heating the rock with hot air with the help of solar air heater when solar insolation is available (day) and then utilizing it as a source of heating when solar insolation is absent (night).Rock bed acts as a regenerator in charging and discharging processes. A schematic of rock bed storage technique is as shown in Fig.1.

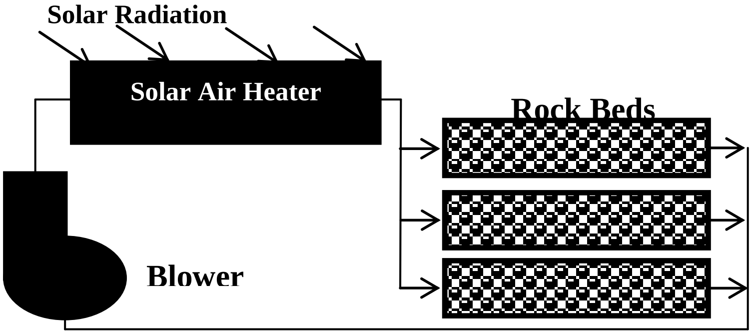


Fig1. Rock Bed Storage System

III. MATERIAL AND METHOD FOR LOAD CALCULATIONS

In this paper, a solar air heater assisted continuous conveyor crop drying system is modeled which consist of a rock bed heat storage system. The rock bed heat storage system stores energy during daytime by passing hot air coming from solar air heater through it. This stored energy is utilized in drying of potato slices & onion flakes during night. The heat storage system stores energy during daytime by passing hot air coming from solar air heater through it. This stored energy is utilized in drying of potato slices & onion flakes during night. The schematic diagram of considered system is shown in the fig 2. The important components of the system are:

- Blower
- Solar air heater
- Continuous conveyor dryer
- Rock bed storage system.

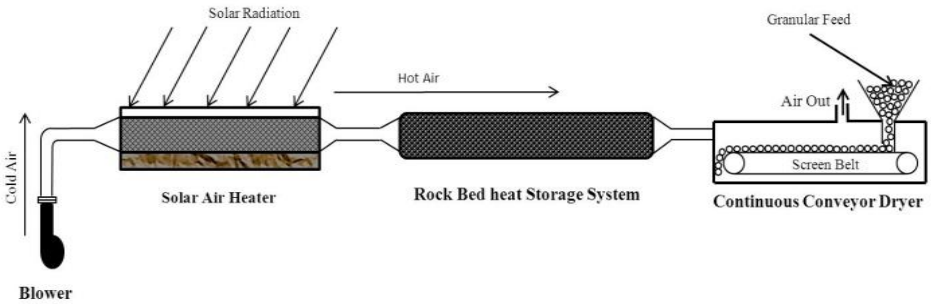


Fig. 2.: Schematic Diagram of Vegetable Drying Process

3.1 Continuous Conveyor Dryer

In **Fig3** a flow diagram is shown from a continuous conveyor type dryer, where the drying air flows counter currently to the vegetables (potato slices and onion flakes). The Vegetables enters at a rate of $m\bullet_s$ kg/sec, having moisture content Xs_1 and temperature Ts_1. It leaves at moisture content Xs_2 and Temperature Ts_2. The gas enters at a rate of $m\bullet_a$ kg dry air/sec, having humidity Xa_2 and temperature $Ta_{2.}$

The air leaves at Ta_1 and $Xa_{1.}$ as shown by **Geankoplis [6].**Here it is assumed that the outlet temperature of both air and vegetables are same ($Ta_1 = Ts_{2)}$.

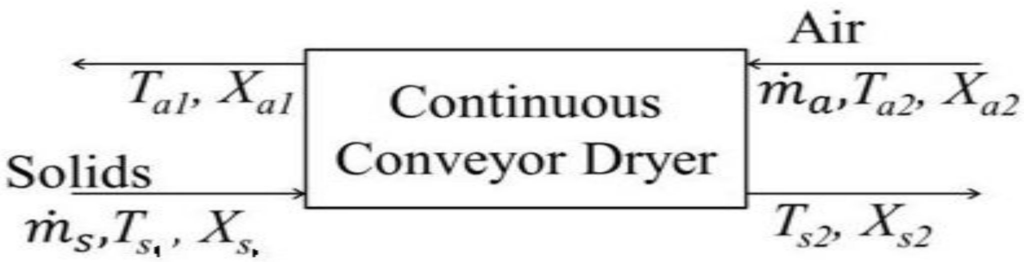


Fig-3- Flow Diagram for a Counter-Current Continuous Dryer

From material balance:

$$m\bullet_a X_{a2} + m\bullet_s X_{s1} = m\bullet_a X_{a1} + m\bullet_s X_{s2} \qquad \textbf{(1)}$$

From energy balance:

$$m\bullet_a h_{a2} + m\bullet_s h_s = m_{\bullet a} h_{a1} + m\bullet_s h_{s2} \qquad \textbf{(2)}$$

Here h_a is the enthalpy of the air in KJ/Kg dry air. It is given by:

$$h_a = C_h(T_a - T_0) + X_a h_{fg},$$

$$C_h = 1.005 + 1.88X_a \qquad \textbf{(3)}$$

h_s is the enthalpy of the grains in kJ/kg dry solid. It is given by

$$h_s = C_{ps}(T_s - T_0) + X_s C_{pv}(T_s - T_0) \qquad \textbf{(4)}$$

IV. MATHEMATICAL MODEL

Many authors have investigated different models based on the set of two coupled partial differential equations: one for the gas and the other one for the solid. For present study mathematical model of heat transfer in rock bed developed by **Murthy *et al.*[7]** is taken.The energy equations associated with charging and discharging of rock bed to each phase i.e. gas and solid in the mathematical model taken are:

For gas: $k_{g,eff} \times \frac{\partial^2 T_g}{\partial x^2} - c_{pg} \times \rho_{pg} \times v_g \times \frac{\partial T_g}{\partial x} + h \times \frac{a_s}{\varepsilon} \times (T_s - T_g) = c_{pg} \times \rho_g \times \frac{\partial T_g}{\partial t}$ **(5)**

For solid:

$$\rho \times c_{pg} \times (1-\varepsilon) \times \frac{\partial T}{\partial t} = h \times a_s \times (T_g - T_s) \quad \textbf{(6)}$$

Initial and boundary conditions:

At t = 0, *Tg = Tgo & Ts = Tso* $0 \le x \le L$ **(7)**

At x = 0, t > 0 $k_{g,eff} \frac{\partial T_g}{\partial x} = c_{pg} \rho_g v_g \varepsilon (T_g - T_{g0})$ **(8)**

The pressure drop across the bed is calculated using **[8,9]:**

$$P = \frac{L_b G^2}{\rho_g dp}\left[\left\{(1.75) * \frac{(1-\epsilon)}{\epsilon^3} + (150) * \frac{(1-\epsilon)}{\epsilon^3} * \frac{\mu}{Gdp}\right\}\right] \quad \textbf{(9)}$$

For calculating the value for the volumetric convective heat transfer coefficient expression suggested by **Coutier and Farber [10]** is used which is as:

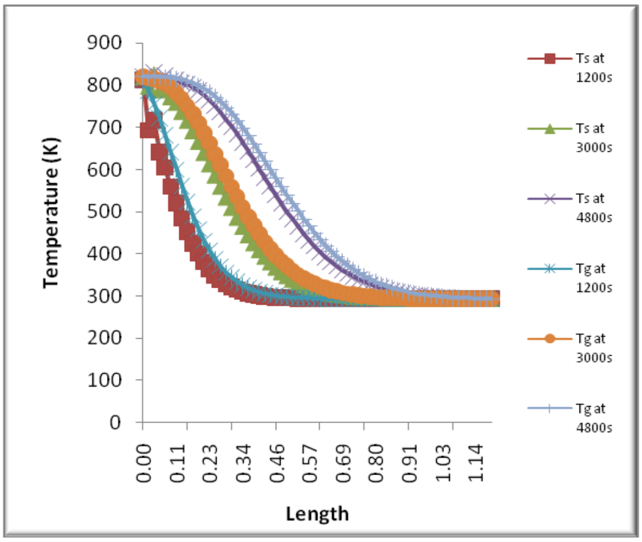
$$h_v = 700 * \left(\frac{G}{dp}\right)^{0.76} \quad \textbf{(10)}$$

The equations shown are coupled partial differential equation in space and time. In this present study the mathematical model which consists of two partial differential equations is coded and solved using a computer program in MATLAB.

Validation of MATLAB Program: The temperature profiles obtained in present work from the MATLAB program have been compared with the profiles obtained from a previous research work done by **Steinfeld *et al.* [11]** in Fig. 4 and Fig.5 from these figures it can be observed that the temperature profiles obtained in present modelling and previous work are very close to each other, which in turn indicates that results obtained are in good agreement with the previous work.For the purpose of calculating the deviation from previous work, a comparison for 1200 seconds has been done on temperature at different length of column. It is observed that a maximum of 7.3% variation is obtained.

V. CALCULATIONS

S.I. Anwar & and G.N. Tiwari [12] made an attempt to calculate the convective heat transfer coefficient operating in crop drying in open sun drying conditions (natural convection). Values of the constants, c and n were obtained by linear regression analysis from experimental data. They also obtained the value of m_{ev} for potato slices and onion flakes with the help of weight calculations performed



Fi.g4-Charging rock bed temperature profiles of present work

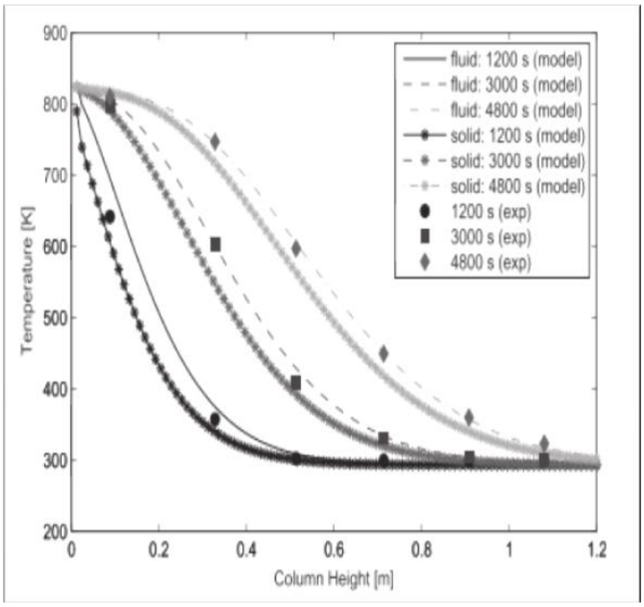


Fig. 5-Charging rock bed temperature profiles of Aldo Steinfeld *et al.* [2011]

at the interval of every 15 minutes. In this paper the mass flow rate of grain required to evaporate particular moisture content from a grain can be calculated with the help of method discussed in equations **(1 to 4).**

Table 1- Various useful Data regarding the vegetables (Potato slices and onion flakes).

S.No	Vegetables	X_{s1}	X_{s2}	Cps	Cpv
1	Potato slices	80% (w.b.)	3%	3.43kJ/kgK	1.88kJ/kg K
2	Onion flakes	86% (w.b.)	7%	3.95 kJ/kgK	1.88kJ/kg K

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Note-Ref .(Arun s. Mujumdar (2014) [13] and f National Center for Biotechnology Information [14])

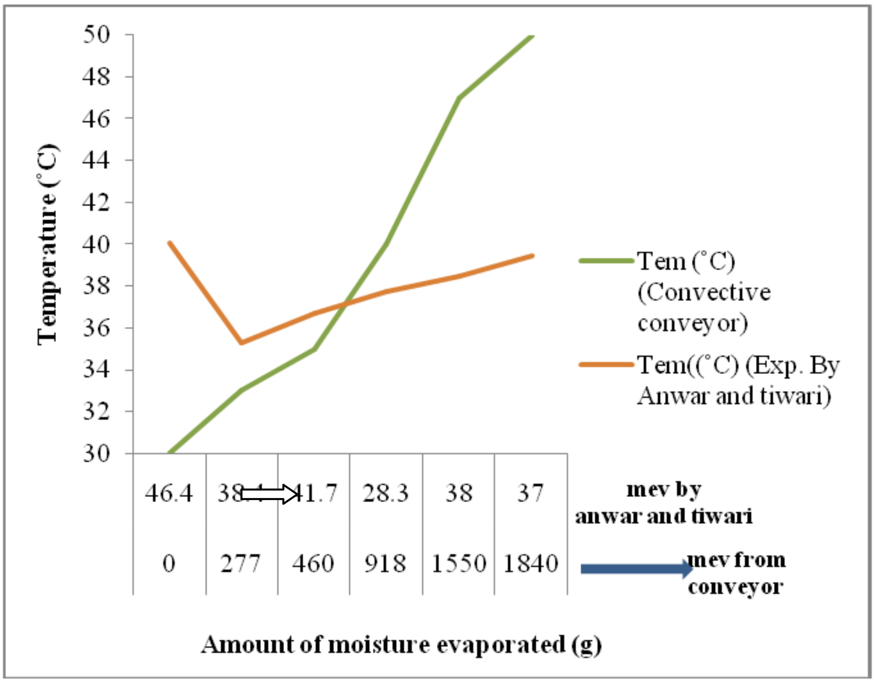

Fig 6- Variation in moisture evaporation (g) with the change in Temperature (Potato slices)

VI. CONCLUSION

With the help of Table1 graphs is been plotted .In the present work a hypothetical examination of dampness evacuation is been finished with the assistance of persistent convective transport, utilizing a stone bed which gets accused at day time of the assistance of sun based air radiator.

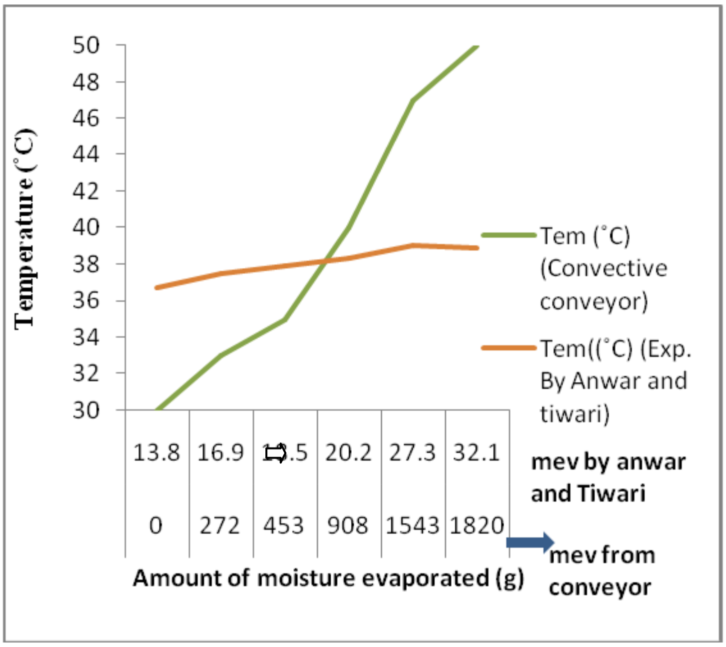

Fig7- Variation in moisture evaporation (g) with the change in temperature (onion flakes)

A steady 50°C air is thought to be having a go at way out of sunlight based air radiator or charging the stone bed amid the entire charging period. Warming burden computation of room at evening is done as well where surrounding temperature of night is thought to be 25°C all through. Present work also includes parametric study of rock bed in charging and discharging mode and obtaining charging and discharging characteristics of rock bed with different particle diameter and mass velocity. Pressure drop across the bed is also calculated. The optimization of bed is done on the basis of space heating with minimum charging time (3.5hours), maximum discharging time (greater than 5 hours) and with least pressure drop across the bed. The consequences of the present work demonstrates that if warm air, in winters, is to be warmed with least power prerequisite and send it to the ceaseless convective transport then the improved bed parameters proposed can be received.

Optimized Bed Parameters -The optimized parameters in present work for air in charging the bed at 50^0C (constant) and discharging the bed at 25^0C (constant) are as follows:

- Length of bed = 1.6 m
- Diameter of bed = 1.15 m
- Number of beds = 1
- Mass velocity of hot air = 0.450 kg/m^2-s (Charging)
- Mass velocity of cold air = 0.225 kg/m^2-s (Discharging).
- Particle diameter = 0.03 m.

Nomenclature-

Symbol	**Description**	**S.I.Unit**
A_c -	Cross sectional area of rock bed -	m^2-
C_v -	Specific Heat of Humid Air -	J/kgK
Cpg-	Specific heat of air -	J/kg-K
C_{ps}-	Specific heat of solid -	J/kg-K
C_{pv}-	Specific Heat of Water Vapour-	1.88kJ/kg K
C_{ps}-	Specific Heat for potato slices-	3.43kJ/kg K
C_{ps}-	Specific Heat for onion flakes-	3.95kJ/kg K
D_b-	Diameter of rock bed -	m
d_p-	Particle diameter -	m
Gr-	Grashof Number	$(g\beta L_c^3\rho^2\Delta T/\mu^2)$
h_p-	Particle heat transfer coefficient -	W/mK
h_v-	Volumetric heat transfer coefficient -	W/m^3K
h_a	Enthalpy of air -	kJ/kg
h_s -	Enthalpy of grain or vegetables-	kJ/kg
h_{fg}-	Latent Heat of vaporization-	(2.256 * 10^3kJ/kg)
$k_{g,eff}$-	Effective thermal conductivity of air -	W/mK
L-	Length of rock bed -	m
L-	Length of bed -	m
m_{ev}-	Moisture evaporated -	kg
Nu-	Nusselt Number	(h_cL_c/K_v)
P-	Pressure drop across rock bed	Pa
Pr-	Prandtl Number	(μC/K)

T_c-	Crop Temperature	˚C
T_{air} -	Air temperature	°C
X-	Specific Humidity	
v-	Velocity of air in rock bed	m/s
μ-	Dynamic viscosity of air	kg/m-s
Symbol	**Description**	**S.I.Unit**
ρ_g	Density of air	kg/m^3
ρ_s	Density of solid	kg/m^3
ϵ	Porosity of rock bed	(0.4)
C	Constant	
n	Constant	

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