



Energy Utilization Efficiency and Entrepreneurial Potential of a Solar-biomass Integrated Drying System

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ABSTRACT

In absence of grid power in most of the production catchments in the North Eastern states of India, coupled with disruptive power situation in areas where it is available, agricultural products are invariably dried under traditional sun drying. Ginger and turmeric with high intrinsic qualities are two major spices produced in a formidable quantity in the region. Truckloads of raw ginger are transported to Delhi and other places, causing huge transit losses. A solar-biomass integrated (IDS) batch drying system was thus designed and developed with a capacity of 100 kg/batch. A compound parabolic solar collector coupled with bio-waste fired combustion and heating assembly was designed and attached to a drying chamber consisting of six trays and a wind turbine on the top to create the necessary draft controlled by butterfly valves and sliding gates. Thin layer drying experiments were carried out for drying of sliced ginger and turmeric. Fluidized bed dryer (FBD), electrical oven (EO) and open sun drying (OSD) were used for comparison. Effective moisture diffusivity in case of turmeric drying was nearly 21% more in comparison to ginger drying. Minimum specific energy consumption (SEC) occurred in IDS, and was 14 and 30 times less compared to FBD and OSD, respectively. Considering total heat available in the plenum chamber and latent heat of vapourization, the IDS showed 36.33% of overall energy utilization efficiency. A run up of 10 years and a break-even of 17.70 % was estimated, reflecting high entrepreneurial possibility of the developed IDS.

The objective of a dryer is to supply the product with more heat than is available under ambient conditions, thereby increasing sufficiently the vapour pressure of the moisture held within the crop, and decreasing significantly the relative humidity of the drying air and thereby increasing its moisture carrying capacity and ensuring a sufficiently low equilibrium moisture content (Ekechukwu, 1987; Akpinar, 2004; Arslan and Ozcan, 2008). In many rural locations of most developing countries, grid-connected electricity and supplies of other non-renewable sources of energy are either unavailable, unreliable or, for many farmers, too expensive. Thus, in such areas, crop drying systems that employ motorized fans and electrical heating are inappropriate.

Among the spices, ginger (*Zingiber officinale*) is grown over a wide area of the tropic, although the major areas of production are Southern and Eastern Asia. India

produced about 50% of the world ginger (Purohit and Michaelowa, 2008) till 2008. India produced 3.07 lakh Mt during 2004-05, which was 50% of the world ginger and to this, contribution of N-E region as a whole was 2.09 lakh Mt (Jha and Deka, 2008). India ranks first in the production of dry ginger, which is produced mainly in Kerala (Purohit, 2009).

Diffusivity reflects the capability of moisture evaporation rate of any material to be dried while keeping other drying conditions under control. Madamba *et al.* (1996) had studied the thin-layer drying characteristics of garlic slices. Karathanos and Belessiotis (1999) gave particular attention to the drying of some fresh and semi-dried fruits. Babalis and Belessiotis (2004) found the effective diffusivity, D_{eff} for figs varied from $8.40 \times 10^{-10} \text{ m}^2 \cdot \text{s}^{-1}$ to $1.13 \times 10^{-9} \text{ m}^2 \cdot \text{s}^{-1}$ for the different values of temperature and air velocity. The values were within the general

range of $10^{-11} \text{ m}^2.\text{s}^{-1}$ to $10^{-9} \text{ m}^2.\text{s}^{-1}$ for food materials (Zogzas *et al.*, 1996). Effective moisture diffusivities identified from modelling presented an Arrhenius-type relationship and mass transfer coefficient was identified ($k = 9.7 \times 10^{-5} \text{ kg water/m}^2/\text{s}$) by Mulet *et al.*, 2005.

Dryers are broadly classified according to their heating sources into conventional dryers and solar-energy dryers. All practical designs of high temperature dryers are conventional dryers, while the low temperature dryers are either conventional or solar-energy based systems. Solar drying of agricultural products in enclosed structures by natural convection is an attractive way of reducing post-harvest losses and low quality of dried products associated with traditional sun-drying (Bena and Fuller, 2002; Chua and Chou, 2003; Chen *et al.*, 2005; Sacilik *et al.*, 2006; Forson *et al.*, 2007).

To overcome the inherent disadvantages of traditional open sun drying as well as to create entrepreneurial potential in the production catchment, the idea of a solar-biomass integrated drying system completely

devoid of grid power dependency was conceived. The work was carried to study the specific energy consumption, comparative performance, energy utilization efficiency and economic potential for entrepreneurial venture.

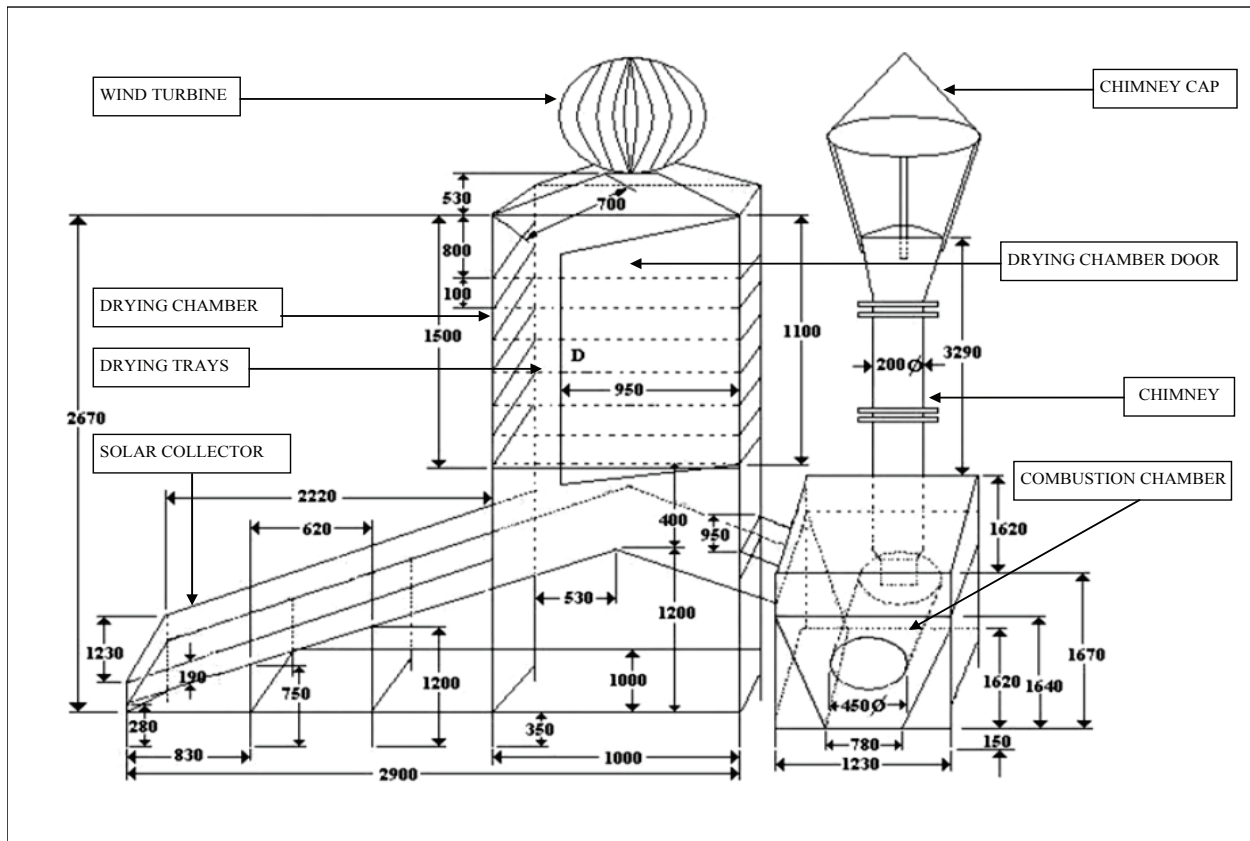
MATERIALS AND METHODS

Raw Material

The present research was undertaken to design and develop a solar biomass-fired integrated drying system (IDS) for drying of ginger (variety: *Australia*) and turmeric (variety: *Megha*) rhizomes (Fig. 1). Ginger rhizomes were washed, surface water removed and manually sliced to 3 - 4 mm in thickness and 50-70 mm in length before being spread on the trays in thin layers. Turmeric rhizomes were washed and boiled in hot water for 1.5 h before slicing to the same sizes as for ginger, and then spread on the trays in thin layers.

Experimental Setup

Functional design of a solar flat plate collector was carried out to harness maximum solar intensity.



(All dimensions are in mm)

Fig. 1: Schematic diagram of integrated drying system

Experiments were carried out at a location 26.75° N, 94.20° E with 116 m height from mean sea level during the month of April and May in five replications.

The collector dimension of 2220 mm × 1230 mm was finalized with an inclination of 15° facing south for maximum exposure to insolation. To increase the intensity of solar radiation, a double parabolic concentrator was designed accommodating 6 parabolic concentrators of outer diameter 32 mm, thickness of 15 mm and length of 1860 mm. They were painted black and placed as receivers along the focus and fitted inside the glass cover with equal spacing of 15 mm. Horizontal and vertical manual tracking was incorporated to provide tracking by 11.54° and 4.68°, respectively. A bio-waste fired assembly with a detachable grate type husk feeding system; combustion chamber (length: 1620 mm, diameter: 450 mm) with a horizontal grate for burning of solid biomass was also designed. The capacity of the dryer was designed for 100 kg per batch in 6 perforated trays. Total cost involvement of the dryer was ₹ 80,000/-.

Along with the developed dryer, drying were also carried out simultaneously in a fluidized bed dryer (FBD) (make: Prism Pharma Machinery; 3.75 kW power; capacity: 1 kg with drying temperature range of 40 to 85 °C), electrical oven (EO) (make: Swastik Scientific Co.; capacity: 27 litre; 2 trays; temperature range 50-250 °C) and open sun drying for comparison.

Thin layer drying

Thin layer drying experiments were carried out in the IDS for drying of sliced ginger and turmeric. Following Fick’s second law, the moisture diffusion during drying spread in the form of thin slabs can be expressed as follows (Crank, 1975):

$$MR = \frac{8}{\pi^2} \left[\sum_{n=1}^{n=\infty} \frac{1}{(2n+1)^2} \exp\left(\frac{-(2n+1)^2 \pi^2 D_{eff} t}{4h^2}\right) \right] \dots(1)$$

For long drying hours, by taking n = 0 (Geankoplis, 2003) it could be reduced to:

$$MR = \frac{M - M_e}{M_0 - M_e} = \frac{8}{\pi^2} \exp\left(\frac{-\pi^2 D_{eff} t}{4h^2}\right) \dots(2)$$

Where,

D_{eff} = Effective moisture diffusivity, m².h⁻¹,

t = Drying time, h, and

h = Thickness of infinite slab dried from top and bottom parallel surfaces, m.

The equation (2) could be rewritten as,

$$MR = Ae^{-kt} \dots(3)$$

Where, the constants are, $A = \frac{8}{\pi^2}$, and $k = \frac{\pi^2 D_{eff}}{4h^2}$

Simplifying it to linear form,

$$\ln(MR) = \ln\left(\frac{M - M_e}{M_0 - M_e}\right) = \ln A - kt \dots(4)$$

A plot of ln (MR) versus drying time gives a straight line with a slope (S). Assuming that drying occurs from top and bottom parallel faces, thickness of the slab to be dried from one face was assumed to be half of the total thickness ‘h’ in metre. The effective moisture diffusivity was calculated using the slope as,

$$A = \frac{8}{\pi^2}, \text{ and } k = \frac{\pi^2 D_{eff}}{4h^2} \dots(5)$$

Instrumentation

The experiment was carried out using the following instruments for measurements of various parameters.

Moisture measurements of samples were done using a digital moisture balance CB-50 (Contech Instrument Ltd., India). A J-type thermocouple (Make-Kimo Instrument, France) was used for measurement of temperature. Air velocity was measured with a velocity transmitter (Make-Kimo Instrument, France). For data acquisition, signals were logged into a 16-channel data logger (Make-R.S. Process System Pvt. Ltd., India).

Solar intensity was measured with a pyranometer (PYRA300V2, Sivara Systems and Solutions, Bangalore).

RESULTS AND DISCUSSION

Diffusivity

The effective moisture diffusivity during drying in IDS was determined using method of slopes shown in Fig. 2 and Fig. 3 for ginger and turmeric, respectively.

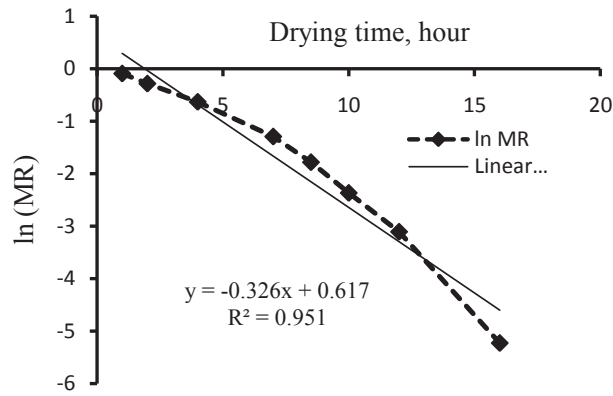


Fig. 2: ln (MR) vs. drying time (ginger)

From Fig. 2, the slope, $k = 0.326$ and considering thickness of slices as half of original thickness (slabs), $h = 1.5 \times 10^{-3}$ m, the effective moisture diffusivity (D_{eff}) for ginger using Eqn. 5 was found to be 2.97×10^{-7} $m^2 \cdot s^{-1}$. While experimenting with turmeric rhizomes, the slope from the curve ln (MR) against drying time (Fig. 3) was found to be $k = 0.411$. Due to similarity in size of turmeric with that of ginger slices, h was taken as 1.5×10^{-3} m, and using Eqn. 5 the effective moisture diffusivity for turmeric was found to be 3.747×10^{-7} $m^2 \cdot s^{-1}$. This was in accordance with the observation of Karathanos and Belessiotis (1999), who observed that simple method of slopes could be used for estimation of diffusivity. From the results, it was observed that diffusivity in IDS was 35.7 % more in comparison to diffusivity reported in literature under sun drying of 1.337×10^{-7} $m^2 \cdot s^{-1}$ (Akpinar and Toraman, 2013). Effective moisture diffusivity in case of turmeric drying was nearly 21% more in comparison to ginger drying. Moisture diffusion was easier in turmeric compared to ginger rhizomes due to its less fibrous nature and blanching treatment.

Specific Energy Consumption

Comparison of specific energy consumption (SEC)

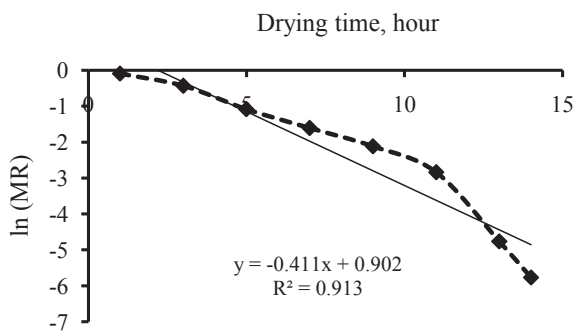


Fig. 3: ln (MR) vs. drying time (turmeric)

was carried out among the selected mechanical drying systems (Fig. 4). During the period of experimentation, the average solar insolation was recorded and found to vary between 430 – 460 $W \cdot m^{-2}$.

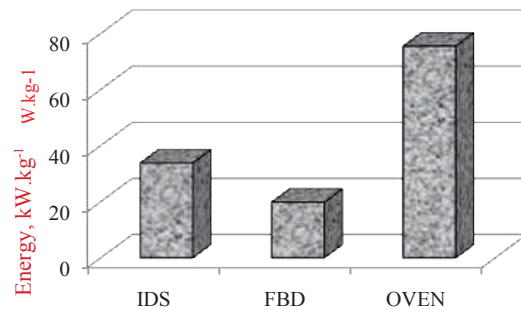


Fig. 4: Specific energy consumption ($kW \cdot kg^{-1}$) for ginger drying

It could be seen that ginger dried in oven consumed maximum specific energy ($75.43 \text{ kW} \cdot \text{kg}^{-1}$) followed by IDS ($33.79 \text{ kW} \cdot \text{kg}^{-1}$). Lowest SEC was in case of FBD ($19.84 \text{ kW} \cdot \text{kg}^{-1}$). However, quality in this case was highly affected due to resultant highest diffusivity, affecting attributes like rehydration ratio, texture, colour, oleoresin and volatile oil.

While comparative SEC values for turmeric drying, it was observed that the energy consumption in evaporating per kg of moisture was highest (18.16 kW) in oven drying attributing to non-uniform exposure of surfaces to the heat supplied. In the IDS, the trays were rotated in a predetermined sequence with stirring of rhizomes at the same time and minimum specific energy consumption of $4.21 \text{ kW} \cdot \text{kg}^{-1}$ was observed (Fig. 5). Similar findings have been reported by Akpinar (2004) for red pepper slices; Sharma and Prasad (2006) for garlic cloves; and Motevali *et al.* (2011) for mushroom slices.

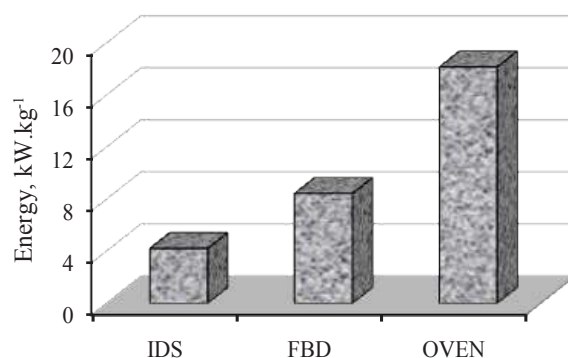


Fig. 5: Specific energy consumption ($kW \cdot kg^{-1}$) for turmeric drying

Drying Time

Experiments to study the comparative performance among IDS, FBD, oven drying and sun drying (control) while reducing the moisture content of ginger from same initial level (86±2%, w.b.) to nearly same final moisture content (7±1%, w.b.) were carried out maintaining near equal temperatures (50±2 °C) in the mechanical drying systems. Initial moisture content of turmeric was 88±1%, (w.b.) and was dried to 6±0.5 %, (w.b.). Considerable variation in time taken to bring down the moisture from the same initial level to near similar final level was observed. Nearly 6 h additional effective drying time was required in open sun drying (30.25 h) in comparison to IDS (24 h) (Fig. 6 and 7).

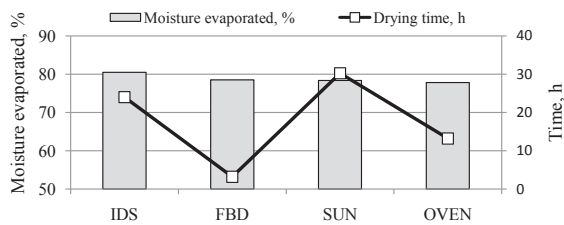


Fig. 6: Comparative performance of drying methods (ginger)

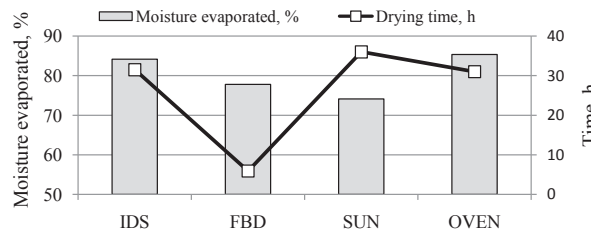


Fig. 7: Comparative performance of drying methods (turmeric)

Energy Utilization Efficiency

Energy utilization efficiency of the developed IDS was carried out for bio-waste fired assembly and compound parabolic solar collector separately.

Energy supplied to combustion chamber

Mass of fuel (rice husk) supplied, $m_f = 26 \text{ kg}$

Calorific value of rice husk, $CV = 3000 \text{ kcal.kg}^{-1}$

Energy supplied to the furnace, $m_f \times CV = 78000 \text{ kcal} = 326352 \text{ kJ}$

Duration of running the furnace = 31 h

Rate of energy supplied to the furnace =

$$326352 / (31 \times 60 \times 60) \text{ kW} = 2.92 \text{ kW}$$

Energy available in plenum chamber from combustion side

$$Q_c = m_c C_p \Delta T_c \quad \dots(6)$$

Where,

m_c = Rate of mass flow = $\rho A v$,

C_p = Specific heat of air at constant pressure = 1.0005 kJ/kg.°K,

$$\Delta T_c = T_h - T_{\text{ambient}} = 343 - 303 = 40^\circ\text{K},$$

P = Density of air at 60°C = 1.0335 kg.m⁻³,

A = Area of cross section through which ambient air was passed

$$= 2(0.23 \times 0.16) = 0.0736 \text{ m}^2 \text{ [No. of cross section=2], and}$$

V = Air velocity = 0.6 m.s⁻¹

$$\text{So, } m_c = 0.0456 \text{ kg.s}^{-1}$$

Therefore, $Q_c = 1.82 \text{ kW}$

Efficiency of the bio-waste fired assembly

$$\eta_c = \frac{\text{Heat available in plenum chamber from combustion side}}{\text{Heat supplied to the furnace}} \times 100 = 62.32 \%$$

Energy available to the compound parabolic solar collector

$$\text{Incident energy, } Q_i = I_a \times A_{\text{collector}} \quad \dots(7)$$

$$= 456.601 \text{ W.m}^{-2} \times 3.73 \text{ m}^2 \text{ [Av. Solar intensity } I_a \text{ was } 456.601 \text{ W.m}^{-2}]$$

$$= 1.689 \text{ kW}$$

Energy available in collector surface area:

Overall heat transfer co-efficient of solar collector:

$$\text{Emissivity of glass cover, } \epsilon_{\text{cover}} = 0.88$$

$$\text{Emissivity of absorber, } \epsilon_{\text{absorber}} = 0.95$$

$$\text{Slope of solar collector with horizontal} = 15^\circ$$

Gap between the absorber and cover, $d = 5\text{ cm}$
 Absolute temperature of air, $T_{\text{air}} = 30+273 = 303 \text{ }^\circ\text{K}$
 Temperature of absorber, $T_{\text{abs}} = 56+273 = 329 \text{ }^\circ\text{K}$
 Temperature of glass cover, $T_c = 38+273 = 311 \text{ }^\circ\text{K}$
 Heat transfer co-efficient of air/wind, $h_{\text{wind/air}} = 7 \text{ Wm}^{-2}\text{K}$
 Stefan Boltzmann constant, $\sigma = 5.67 \times 10^{-8} \text{ W.m}^{-2}.\text{K}^{-4}$

For radiation to the sky from glass cover,

$$h_{r,c-a} = \epsilon_c \sigma (T_{\text{cover}}^2 + T_{\text{air}}^2)(T_{\text{cover}} + T_{\text{air}}) \quad \dots(8)$$

$$= 5.775 \text{ W. m}^{-2}.\text{K}$$

For radiation from absorber plate to cover,

$$h_{r,p-c} = \frac{\sigma(T_{\text{absorber}}^2 + T_c^2)(T_{\text{absorber}} + T_c)}{\frac{1}{\epsilon_{\text{absorber}}} + \frac{1}{\epsilon_{\text{cover}}} - 1} \quad \dots(9)$$

$$= 6.255 \text{ W. m}^{-2}.\text{K}$$

Rayleigh Number:

$$Ra = \frac{g\beta \Delta T L^3}{\nu \alpha} \quad \dots(10)$$

Where,

$g =$ Acceleration due to gravity $= 9.81 \text{ m.s}^{-2}$.

$\beta =$ Thermal expansion coefficient $= 1/T = 3.125 \times 10^{-3}$,
 $T = (38+56)/2+273$,

$\Delta T = 56-38 = 18 \text{ }^\circ\text{K}$,

$L = 0.05 \text{ m} = 5 \text{ cm}$,

$\nu =$ Kinematic viscosity of air at $32^\circ\text{K} = 15.68 \times 10^{-6} \text{ m}^2.\text{s}^{-1}$

$\alpha =$ Thermal diffusivity of air at $32^\circ\text{K} = 22.07 \times 10^{-6} \text{ m}^2.\text{s}^{-1}$

Therefore, $R_a = 19.4 \times 10^4$

Nusselt Number (Hollands *et al.*, 1976)

$$Nu = 1 + 1.44 \left[1 - \frac{1708}{Ra \cos \Theta} \right] \left[1 - \frac{(\sin 1.8\Theta)^{1.6} \times 1708}{Ra \cos \Theta} \right] + \left[\frac{(Ra \cos \Theta)^{1/4}}{(5830)^{1/3}} - 1 \right] \dots(11)$$

Hence, $Nu = 4.6$ (slope, $\Theta = 15^\circ$)

Convective heat transfer co-efficient from plate to cover,

$$h_{p-c} = Nu \frac{k}{L} \quad \dots(12)$$

$= 2.6 \text{ W.m}^{-2} \text{ }^\circ\text{K}$ (Thermal conductivity of air, $k = 0.02816 \text{ W.m}^{-1}.\text{K}^{-1}$)

Hence, the top heat loss co-efficient,

$$U_t = \left[\frac{1}{h_{p-c} + h_{r,p-c}} + \frac{1}{h_{r,c-a} + h_{\text{wind/air}}} \right]^{-1} \quad \dots(13)$$

$= 5.28 \text{ W.m}^{-2}.\text{K}$

Considering negligible edge and bottom loss due to insulation, (i.e. U_e and $U_b = 0$) overall heat loss co-efficient was calculated:

$$U_L = (U_t + U_e + U_b) = 5.28 \text{ W.m}^{-2}.\text{K}^{-1}$$

Therefore, rate of heat loss,

$$Q_o = U_L A (T_{\text{abs}} - T_{\text{air}}) \quad \dots(14)$$

$$= 511.999 \text{ W}$$

Amount of solar radiation received by the collector

$$= 511.999 \text{ W} \quad \dots(15)$$

$$Q_i = 1689.42 \text{ W}$$

Thus, the rate of useful energy extracted by the collector,

$$Q_u = Q_i - Q_o = 1177.438 \text{ W}$$

Heat available in the plenum chamber from solar side:

Temperature at inlet of the solar collector,

$$T_i = T_{\text{ambient}} = 30+273 = 303^\circ\text{K}$$

Temperature at outlet of the solar collector, $T_o = 46+273 = 323^\circ\text{K}$

Hence, $\Delta T_s = T_o - T_i = 20^\circ\text{K}$

Heat carried away by the air from the solar collector at a velocity of 0.2 m.s^{-1} (measured) is given by,

$$Q_{\text{actual}} = mC_p(T_{\text{outlet}} - T_{\text{inlet}}) \quad \dots(16)$$

Where, [area = 0.23 m^2 and humid volume (at 46°C and 80% humidity) = $0.885 \text{ m}^3.\text{kg}^{-1}$]

$$\text{Mass flow rate, } m = \frac{\text{Cross sectional area of collector} \times \text{Velocity of air}}{\text{Humid volume of air at } 46^\circ\text{C}80\%\text{RH}} = 0.0519 \text{ kg.s}^{-1}$$

$$\text{Since, } C_p = 1.0005 \text{ kJ.Kg}^{-1}.\text{K}; Q_{\text{actual}} = 832.416 \text{ W}$$

Collector heat removal factor,

$$F_r = \frac{Q_{\text{actual}}}{Q_u} = 0.70$$

The instantaneous thermal efficiency of the collector:

$$\eta = \frac{Q_{\text{actual}}}{AI} \times 100 = 49.27\%$$

Total heat available in the plenum chamber

$$Q_{\text{TOTAL}} = Q_c + Q_s \quad [\text{where, } Q_s = \text{Solar } Q_{\text{actual}}]$$

$$= 1.82 + 0.832 = 2.656 \text{ kW}$$

Heat utilized in the drying chamber:

By solar power:

$$\text{Latent heat of evaporation of water at } 46^\circ\text{C, } h_{\text{fg}} = 2392.4 \text{ kJ.kg}^{-1}$$

$$\text{Amount of moisture removed} = 3.2 \text{ kg}$$

$$\text{Therefore, amount of heat utilized} = 7655.68 \text{ kJ}$$

Or, rate of heat utilized for 8 hours

$$= 7655.68 \div (8 \times 60 \times 60) = 265.822 \text{ W} \quad \dots(\text{A})$$

By biomass power:

Latent heat of evaporation of water at 55°C ,

$$h_{\text{fg}} = 2373.1 \text{ kJ.kg}^{-1}$$

$$\text{Amount of moisture removed} = 24.4 \text{ kg}$$

$$\text{Therefore, amount of heat utilized} = 57903.64 \text{ kJ}$$

Or, rate of heat utilized

$$= 57903.64 \div (23 \times 60 \times 60) = 699.319 \text{ W} \quad \dots(\text{B})$$

$$\text{Total heat utilized from both power source, (A)+(B)} \\ = 965.141 \text{ W}$$

Overall energy efficiency of drying system:

The overall energy efficiency of the designed IDS was evaluated following the standard method of energy utilized to energy supplied:

$$\eta_o = \frac{\text{Energy utilized in the drying chamber}}{\text{Total energy supplied to dryer}} \times 100 = 36.33 \%$$

A direct-type natural convection solar dryer combined with a simple biomass burner was evaluated by Bena and Fuller (2002) for drying of pineapple. Drying efficiency of the solar component alone was found to be 22 % and they estimated the efficiency of the burner in producing useful heat for drying to be 27 per cent.

Economic Analysis

Economic analysis of the IDS as a business proposition was carried out (Table 1). Assuming annual variable cost increases by 0.05%, selling price increases by 0.03 %; ginger is dried for 4 months and turmeric for 6 months per year, for a run up of 10 years of the IDS as an entrepreneurial venture, an economic analysis for expected return on investment (Table 2) resulted in a BEP of 17.70.

CONCLUSIONS

Effective moisture diffusivity in case of turmeric drying was nearly 21% higher in comparison to ginger drying in the designed IDS. However, the values in both the cases were in accordance with observations reported in literature. Energy utilization efficiency by the solar collector assembly was 49.27 per cent. Energy utilization efficiency of the bio-waste fired assembly was 62.32 per cent. Considering total heat available in the plenum chamber and latent heat of evaporation, the IDS showed 36.33 % of overall energy utilization efficiency. Highest SEC was in case of oven drying, followed by IDS and FBD for ginger drying. However, in case of turmeric drying minimum SEC was in IDS, followed by FBD and oven drying. The developed solar-biomass integrated drying system independent of grid power was found to have full potential at BEP 17.70, to be taken up as entrepreneurial venture in and around production catchments.

Table 1. Economic analysis of IDS

Cost component	Quantity, kg	Rate, ₹	Amount, ₹
A. Fixed Capital			
Cost of machinery and equipment (IDS)			
a. Integrated solar dryer	1	80000.00	80000.00
b. Misc. utensils			20000.00
Sub-total (A)			100000.00
B. Working capital per month for ginger			
a. Ginger for 6 batch @ ₹ 30/- kg (100 kg/batch)	600	30	18000.00
b. Rice husk for 6 batch(19.2 bag) @ ₹ 10/- bag	192	10	1920.00
c. Packaging and labels	80	5	400.00
d. Wages: 1 Man per day × 25 @ ₹ 150/-	25	150	3750.00
e. Miscellaneous			500.00
Sub-total (B)			24570.00
C. Working capital per month for Turmeric			
a. Turmeric for 6 batch @ ₹ 20/-kg (100 kg/batch)	600	10	6000.00
b. Rice husk for batch (16 bags) @ ₹10/-bag	160	10	1600.00
c. Packaging and labels	80	5	400.00
d. Wages: 1Man per day × 25 @ ₹ 150/-	25	150	3750.00
e. Miscellaneous			500.00
Sub-total (C)			12250.00
D. Total capital investment			
	Ginger		Turmeric
a. Fixed capital	100000.00		100000.00
b. Working capital per month	24570.00		12250.00
Sub-total (D)	124570.00		112250.00
Cost of production per month			
a. Working capital	24570.00		12250.00
b. Depreciation on P & M, 10% per annum	800.00		800.00
c. Interest, 12% per annum	1654.00		1176.00
Sub-total (E)	27024.00		14226.00
E. Expected turnover per month			
a. Dry ginger @ ₹ 300/kg x 20% recovery i.e 120 kg	36000.00		
b. Dry turmeric @ ₹ 150/kg x 20% recovery i.e 120 kg			18000.00
F. Expected profit per month			
a. By receipt	36000.00		18000.00
b. Less cost of production	27024.00		14226.00
c. Net Profit per month	8976.00		3774.00
Annual			
d. Gross: Ginger 4 months	144000.00	Variable cost, ginger =	108096.00
e. Gross: Turmeric 6 months	108000.00	Variable cost, turmeric =	85356.00
Total gross per year	252000.00	Total variable cost per year =	193452.00

Table 2. Return on investment

Year	Investment, ₹			Return, ₹	
	Fixed	Variable	Total	Gross	Net
1	100000.00	193452.00	293452.00	252000.00	-41452.00
2	0.00	203124.60	203124.60	264600.00	61475.40
3	0.00	207187.09	207187.09	272538.00	65350.91
4	0.00	217546.45	217546.45	280714.14	63167.69
5	0.00	228423.77	228423.77	289135.56	60711.80
6	0.00	239844.96	239844.96	297809.63	57964.67
7	0.00	251837.21	251837.21	306743.92	54906.71
8	0.00	264429.07	264429.07	315946.24	51517.17
9	0.00	277650.52	277650.52	325424.62	47774.11
10	0.00	291533.04	291533.04	335187.36	43654.32
Total	100000.00	2375028.70	2475028.70	2940099.48	465070.78

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