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RESEARCH ARTICLE

Evaluation of solar tunnel dryer for green leaves drying

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ABSTRACT

Solar tunnel dryer having 30 m^2 area was fabricated, developed and evaluated at Department of Renewable Energy Engineering, CAET, Dediapada. The performance of solar tunnel dryer was tested at no load and with load condition. Maximum average temperature was observed during no load test in solar tunnel dryer was 45.6 °C and solar intensity was 496 W/m^2 at 1 p.m. as ambient temperature was 28.3 °C, with relative humidity 70 percent. Maximum average temperature was observed during load test of all selected green leaves drying was 46.6 °C and solar intensity was 496 W/m^2at 1 p.m. as ambient temperature was 28.5 °C , average humidity 45 % and average wind speed observed as 1.1 m/s. Initial moisture content of Sargava, Neem, Heena and Tulsi leaves were observed as 69.6 %, 74.67 %, 62.8% and 71.30 % respectively. Time required to remove moisture up to storage moisture content as below 10 % from Sargava, Neem, Heena and Tulsi leaves as 8 hours, 6 hours, 8 hours and 8 hours respectively. In open condition time required to remove moisture content up to 26.8 % from Sargava leaves was 8 hours whereas in same time only 46.9 % moisture removed from Heena leaves.

Keywords: Drying, Green leaves, Moisture content, Solar intensity, Tunnel dryer

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INTRODUCTION

Drying in Dediapada, one of the tribal regions of Gujarat, the farmer has taken traditional crops in his field but there was no higher productivity. In this region, at present the selected crops like Sargava leaves *(Moringa oleifer),* Henna leaves *(Lawsonia inermis L),* Neem leaves *(Azadirachta indica)* Tulsi *(Ocimum basilicum)* shown mostly on the bund of field or road sides. These crops required less water and less fertile land and chances of good productivity in future in area if this practice adopted by farmer. This region is endeavoured with the average solar energy availability of 450-600W/m^2 for 7-8 hrs in a day for 300 days in year. Solar tunnel dryer is a simple treatment of drying of green leaves. In solar tunnel dryer, the dryer is fulfilled by the green leaves of Sargava leaves, Henna leaves, Neem leaves and Tulsi etc on tray. Leaves is also a good source of Protein, Vitamin E, Riboflavin and Niacin, and a very good source of Dietary fiber, Vitamin A, Vitamin C, Vitamin K, Vitamin B6, Calcium, Iron, magnesium, Phosphorus, Potassium, Zinc, Copper and Manganese. Henna leaves Skin care products. Henna oil is used for rheumatic and arthritic pains. The henna oil is applied to hair to prevent it from greying. Saragava leaves Calcium content in drying leaves 90%. Saragava leaves can lower cholesterol. Saragava leaves are very nutrition. Drying is most use full unit operation and using the solar energy we can improve the drying rates in low cost (Kuchi et al., 2014). So we develop the solar tunnel dryer which has low construction cost and use full for small farmer for drying of green leaves and earn

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good money (Verma, 2017). The aim of our research work is to develop highly efficient solar tunnel dryer for drying of green leaves is of simple construction, applicable in small units of production with low cost.

MATERIALS AND METHODS

On the basis of moisture available in green leaves, drying rate required for the mass of moisture to be removed by solar heat and drying time, The quantity of air needed for drying may be estimated from the energy balance equations, Volume flow rate of air required was determine by considering weight of air and total drying time then total useful energy required to evaporate moisture was determined, from the total useful heat energy required to evaporate the moisture from the green leaves and the net radiation received by the collector, the solar drying system collector area A_c in m^2 was determined and then dimension of solar tunnel dryer and no of trays to be kept inside the dryer is determined and after that air vent dimension and dimension of chimney were calculated with standard formulas.

Detail of solar tunnel dryer

A solar tunnel dryer having 30 m^2 area was fabricated in the workshop and evaluated at the college campus, Department of Renewable Energy, CAET, Dediapada. The experiments were conducted during sunny days of November 2016. The study was conducted in Dediapada taluka is situated in the Narmada District in south gujarat agro climatic zone of gujarat state at 21° 66' n latitude and 73° 59' e longitude with an elevation of 169 m above mean sea level covering an area of 1026.84 km (Lakkad *et. al.* 2016). The solar tunnel dryer was fabricated in semicircular structure using 35 mm MS angle iron for making 6 arc of 3 m diameter, 15.6 m in length, and 40 mm MS angle were used as based structure of 1m length. The corners are well polished and laminated in order to avoid damage to the polythene sheet. The concrete structure of size 3 m×10 m was used as base of the solar tunnel dryer.

A heated air passed directly through the material bed. This heated air carried moisture from the wet green leaves while it was passing through the bottom of the green leaves bed of independent layers. Finally the air was discharged from the dryer through the chimney at an elevated location. The schematic diagram of solar tunnel drier for green leaves drying is shown in Figure 1. The technical specification of solar tunnel dryer is shown in Table 1.

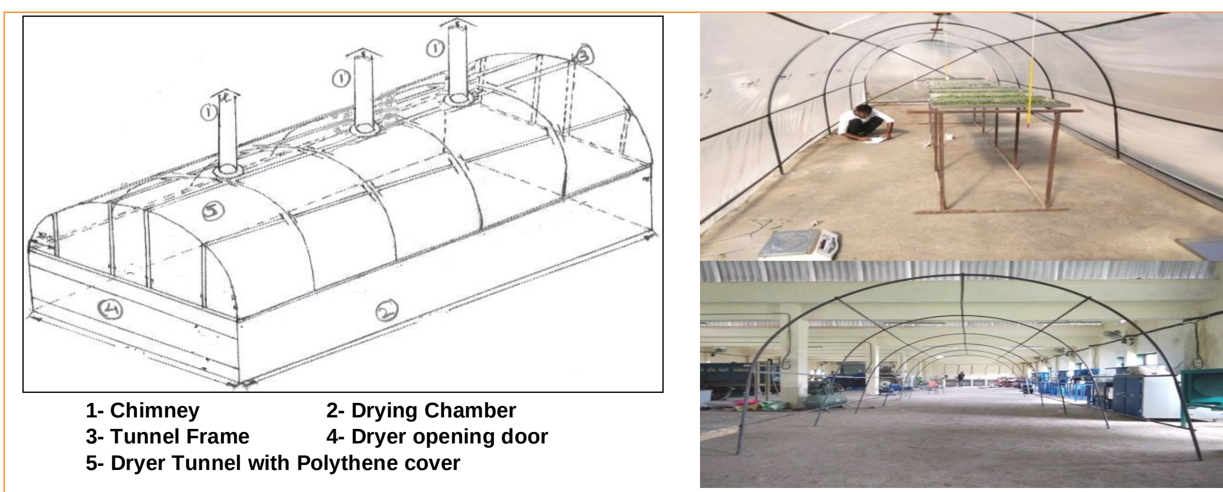

Figure 1. Solar tunnel dryer for green leaves drying

Table 1. Technical specification of solar tunnel dryer

S. No.	Part	Specifications (m)	Material
1.	Drying chamber	10 x 3 x 2	M. S. angle
2.	Tunnel (Semi circular)	Dia. -3, Ht. - 2	M.S. angle
5.	Drying tray	4 x 1 x 0.25	M.S. angle
6.	Cover of tunnel	4 x 12	UV protected polythene
7.	Opening Door	1.2 x 1.7	G.I. sheet
8.	Chimney	Ht. –0.43 , Dia. – 0.15	PVC pipe

Performance evaluation of solar tunnel dryer

The performance evaluation of solar tunnel dryer was carried out as per design layout for drying of selected green leaves. The performance was carried by conducting the no load test for testing designed parameters and loaded test in comparison with open solar drying.

No load test

No load test of solar tunnel dryer was carried out to evaluate the design parameters without loading of dryer. Different parameters like temperature at various places, relative humidity, solar intensity and wind velocity was measured at an interval of one hour in a clear sunny day. Observations were measured by using different digital instrument. The various instrument used during the test with technical specification are summarized.

Load test

Different selected leaves as Sargava leaves, Neem leaves, Henna leaves and Tulsi leaves were put inside the solar dryer for drying as shown in Figure 3. The different parameters were observed as moisture content and drying rate as follows.

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Load test

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Figure 2. Drying of green leaves under solar tunnel dryer and open sun drying

Moisture Content

The percentage moisture content was determined by using following formula.

$$\text{M.C.(w.b.) } \% = \frac{(W_1 - W_2)}{W_1} \times 100$$

$$\text{M.C.(d.b.) } \% = \frac{(W_1 - W_2)}{W_2} \times 100$$

Where, W_1= weight of sample before drying, gram

W_2= weight of bone dried sample, gram

Drying Rate

The drying was carried out by loading the weighted sargava, tulsi, neem and henna in dryer from morning 10:00 am to 17:00 pm and 10:00 am to 15:00 pm respectively. The sargava, tulsi, neem and henna were dried up to the final moisture content of 6.6 %, 9.4 %,9.7 % and 9.2 % (d.b.) respectively. The drying time required for drying the sargava, tulsi, neem and henna sample from IMC 71.6 %, 74 %, 62.8 % and 77 % (d.b.) in solar tunnel dryer condition was critically observed.

RESULTS AND DISCUSSION

A Solar tunnel dryer was fabricated in the workshop of college of Agricultural Engineering and Technology (CAET) Dediapada. The performance of the device was carried out at college campus of CAET Dediapada. The experiment was conducted during the winter days of November 2016; solar tunnel dryer was tested with no load and load test along with environment data such as ambient temperature, ambient relative humidity and wind speed, inside temperature, inside relative humidity, solar insolation and cumulative drying.

Design of solar tunnel dryer

As per methodology adopted in, detail design calculation for drying of green leaves is summarized in following Table 2.

Table 2. Design detail of solar tunnel dryer for drying of green leaves

S. No.	Particulars	Symbol	Design parameter of solar tunnel dryer
1	Amount of moisture to be removed	W_w	W_w =100×(72-8)/(100-8)
2	Average drying rate	W_{dr}	W_{dr} = 78.05/11
3	The quantity of air required for drying	W_a	W_a = (78.05×570) / (0.2426×1.025×20)
4	Volume flow rate of air required	Q_a	Q_a =8945.47 /11 =813.22 m^3/hr
5	Useful heat energy required, (kJ)	E_u	E_u = 813.22 × 0.2426 ×1.025 ×20
6	Total collector area, (m^2)	A_c	A_c = 4044.34 / 650 × 0.20 = 30 m^2
7	Dryer dimensions	Area	Area = 3 × 10 m^2
8	Number of tray		4 trays are required
9	Air vent dimensions	A_v	A_v =813.22 /1200 =0.68 m^2
10	Dimensions of chimney	a_c ,d, v_e , q_e	v_e =8945.47 /1.025 =8727.29 m^3 q_e = 8727.29 / 11 =793.93 m^3/hr

Performance Evaluation

A solar tunnel dryer was evaluated during November month; Device was tested with no load and load test and compared with open sun drying. The description regarding evaluation in month of November is described as follows.

No load test of solar tunnel dryer

The maximum average temperature was observed during no load test in solar tunnel dryer was 45.6 ^{o}C at 1 p.m. and the same time solar intensity was 496 W/m^{2}, ambient temperature was 28.3 ^{o}C, and outside relative humidity was 70 percent. The trend obtained in no load test during performance test is as shown in Figure 3. It clears that the temperature inside the solar tunnel dryer increases with solar intensity increased up to 1 P.M., and then start decline as day progressed.

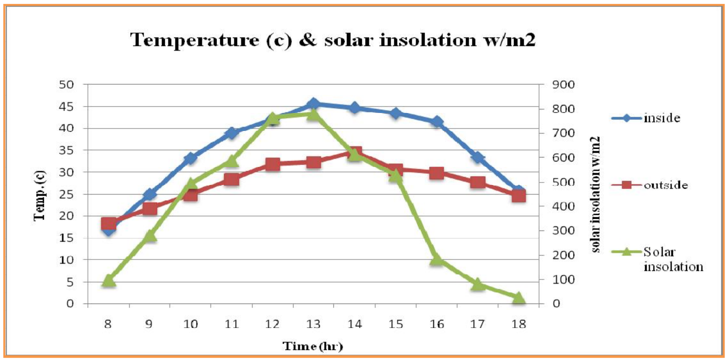

Figure 3. Performance of solar tunnel dryer at no load

Load test of solar tunnel dryer

Sargava leaves *(Moringa Oleifera)*, Neem leaves (*Azadirachta indica*) , Henna leaves *("Lawsonia inermis L")* and Tulsi leaves *(Ocimum basilicum)* were dried inside the solar tunnel dryer with observing weight of sample of these selected leaves, initial moisture content, final moisture content, drying rate, solar intensity, ambient temperature, relative humidity, wind speed, inside temperature. Hourly weight loss and drying rate was observed during the study of solar tunnel dryer. The maximum average temperature was observed during load test of all selected green leaves drying was 46.6 ^{o}C at 1 p.m. and the same time solar intensity was 496 W/m^{2}, ambient temperature was 28.5 ^{o}C , average humidity was 45 % and average wind speed observed as 1.1 m/s depicted in Table 3 .

Sargava leaves *(Moringa Oleifera)*

While drying of Saragva leaves initial moisture content was 71.6 % observed and total time required to reach safe moisture content as 7 % was 8 hours. The drying rate, moisture content was observed is depicted in Figure 4. The initially moisture removed very fast and as drying time passed is become decreased in all type of drying.

Henna leaves *(Lawsonia inermis)*

In the month of November the experiment observation are shown in Figure 5. for henna leaves. The initial moisture content of henna leaves was 77 %. The time required to drying henna leaves up to safe moisture content as 9.2 % was 6 hours. It was observed that the reduction in moisture content was high at beginning and reduced gradually with time. The relationship between moisture content with time and drying rate with time. The drying rate was very high initially but decreased gradually with reduction in moisture content.

Table 3. Different parameter under solar tunnel dryer

Time (hr)	Insolation (w/m^2)	Temperature (°C)		R.H. (%)		Wind speed (m/s)
		Inside	outside	Inside	outside	
10	100	36.5	21.2	39.5	59	0.2
11	290	41.5	27.5	33.1	51	0.5
12	500	44.5	32.3	28.9	60	0.8
13	590	46.0	32.0	27.3	59	1.0
14	760	46.5	31.5	20.8	63	1.5
15	770	44.3	30.5	23.7	61	1.3
16	630	42.7	29.5	19.3	49	1.2
17	570	34.5	28.0	46.5	48	0.6

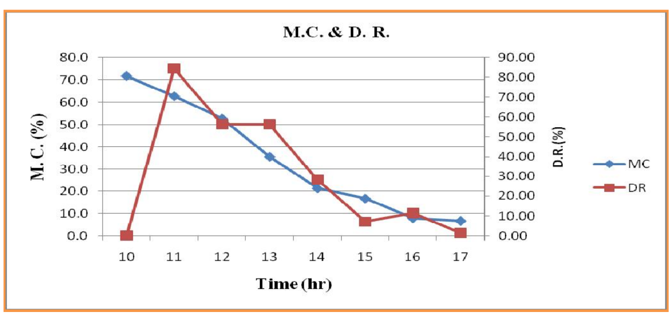

Figure 2. Performance of solar tunnel dryer with sargava leaves

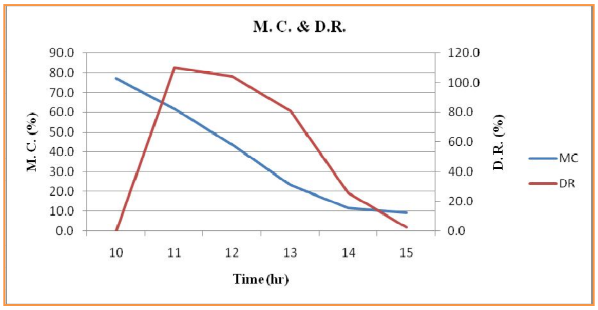

Figure 3. Performance of solar tunnel dryer with henna leaves

Tulsi leaves *(Ocimum basilicum)*

Figure 6 shows the data on drying of tulsi leaves. The initial moisture content of tulsi leaves was 74 % and total time required to reach safe moisture content as 9.4 % was 8 hours. It was observed that the reduction in moisture content was high at the beginning and reduced gradually with drying time. The drying rate was very high initially at high moisture content but decrease gradually with reduction in moisture content. The maximum drying rate was observed in first two hours and then started as declined.

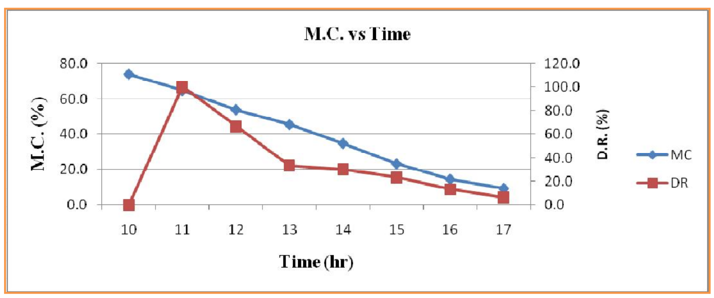

Figure 4. Performance of solar tunnel dryer with tulsi leaves

Neem leaves (*Azadirachta indica*)

The data on drying of neem leaves was presented in Figure 7. The initial moisture content was 62.8 % observed. The time required to dry neem leaves up to 9.7 % moisture content was 8 hours in month of November. It was observed that the reduction in moisture content was high at the beginning and reduced gradually with drying time. The relationship between moisture content and time and drying rate and time. The maximum drying rate was observed 48.4 %.

Open sun drying

In the month of November Open sun drying was taken in college campus with two different green leaves Sargava leaves *(Moringa Oleifer)* and henna leaves *(Lawsonia inermis L.)* the maximum average temperature was observed during the open sun drying was 32.4 ^{o}C at 1 P.M. and at same time maximum solar radiation 780 W/m^2 was observed and average maximum wind speed 1.1 m/s was observed shown in Table 4.

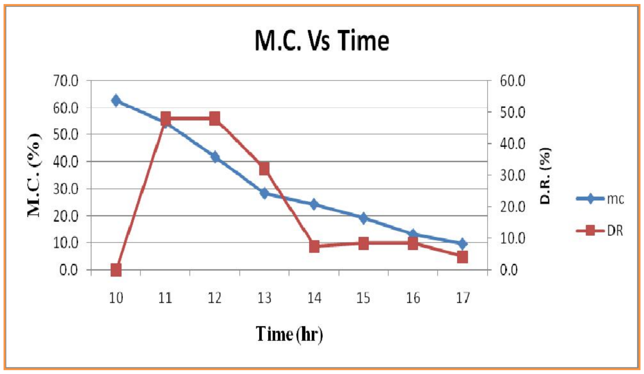

Figure 5. Performance of solar tunnel dryer with neem leaves

Table 4. Different parameter under open sun drying

Time (hr)	Solar insolation W/m^2	Relative humidity (%)	Temperature (^{o}C) outside dryer	Wind Speed (m/s)
8	100	72.7	14.4	0.4
9	282.3	63.4	18.8	0.7
10	496.3	51.3	24.9	0.8
11	589.3	40.2	28.4	1.1
12	763.7	34.7	31.9	1.8
13	780	28.1	32.4	1.9
14	613.3	24.1	32.4	1.8
15	530	25.3	30.7	1.2
16	185.3	21.3	30.0	1.1
17	82.7	50.5	27.8	0.8
18	27	86.3	24.7	0.5

Comparison of solar tunnel dryer and open sun drying

While comparing the drying of selected green leaves with open sun drying with solar tunnel dryer, open sun drying required more than 50 % time to dry up to safe moisture content and removal of moisture is very slow in open sun drying compared to solar tunnel dryer. Solar tunnel drying also fascinated dust free drying without disturbing birds and animal interventions as shown in Figure 2.

CONCLUSION

Simply constructed solar tunnel dryer without insulation and noth wall is suitable for low temperature drying of green leaves as Sargava leaves, Neem leaves, Henna leaves and Tulsi. Time required removing moisture upto storage moisture content as below 10 % from Sargava leaves, Neem leaves, Henna leaves and Tulsi leaves as 8 hours, 6 hours, 8 hours and 8 hours respectively. In open sun drying double time is require with comparing solar drying technology.

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