JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Development and Performance Evaluation of Large Capacity Solar Tunnel Dryers for Drying of Shatavari (Asparagus racemosus)

G. H. Funde[1], V.P. Khambalkar, [2] P.A. Gawande[3] and K. S. Bhonde[4]

[1]M.Tech. Scholar, Department of UCES & EE Dr. PDKV, Akola
[2]Assistant Professor, Department of Agricultural Engineering Section, Dr. PDKV, Akola
[3]Assistant Professor, Department of Soil and Water Conservation Engineering, Dr. PDKV, Akola
[4]Agricutural Assistant, Department of UCES & EE , Dr. PDKV,Akola

Abstract:

The objective of this paper is to develop the solar tunnel dryers for drying of Shatavari roots and to evaluate its techno-economic performance. The solar tunnel dryers were used to dry Sahatavari roots by natural convection. Two solar tunnel dryers, one from polyethelene sheet (STD-PE) and second from PVC film (STD-PVC), were developed with the capacity of 500 kg and 300 kg respectively. The area of solar collector for STD-PE and STD-PVC were 49.847 m^2 and 26.847m^2 respectively. Shatavari roots were successfully dried in both the dryers simultaneously. It was observed that drying time was reduced in tunnel dryer with polyethelene sheet as compared to tunnel dryer with PVC film and open sun drying. The quantitative analysis showed that the traditional drying i.e., open sun drying took 7-10 days to dry Shatavari roots while the solar tunnel dryers took 4-5 days for the drying of Shatavari roots. Shatavari roots were dried from initial moisture content of 84% (wb) to 7% (wb) in STD-PE, 84% to 9% in STD-PVC and 84% to 11.34 % in OSD. An average saving in drying time for the two models of solar tunnel dryers was found to be 50 % as compared to OSD. The efficiency of STD-PE was found to be 17% whereas efficiency of STD-PVC was found to be 14.77%. On the basis of economic analysis payback period for STD-PE were found to be 10 months 27 days and for STD-PVC it was 7 months 23 days for Shatavari roots drying.

Keywords: Solar tunnel dryer, Sahatavari roots, polyethelene sheet, PVC film, moisture content

Introduction

Drying process plays a crucial role in post-harvest technology for preservation of agricultural products. By solar drying, huge amount of national revenue can be saved by avoiding the spoilage of agricultural products due to non-availability of conventional processing facilities. In the drying process, food material is preserved by evaporating a significant amount of water to prevent it from decay and spoilage. In different agricultural produce, moisture contents can be up to 85% (w.b). Solar drying is a clean and hygienic way to process the produce according to international standards without any expenditure on energy costs. In the present scenario, solar energy is successfully being utilized for the drying of the agricultural produce, as well as it can be used as a supplement to artificial drying systems (Muhlbauer,1986).

Drying is an excellent way to preserve food and open sun drying is the oldest agricultural practice to preserve food. Drying is a unit operation widely followed under value addition. Since drying is a cost-intensive operation, use of solar energy is preferable as it is a non-exhaustive and eco-friendly practice.Solar drying has been considered as one of the most promising areas for the utilization of solar energy, especially in the field of food preservation. Solar dryers are the best alternatives to traditional drying because mechanical drying is not affordable by small farmers.

Asparagus is a creeper of the plant genus *Asparagus*. It contains adventitious root system with tuberous roots. For each plant, many tuberous roots are present. It grows wild in forest and also planted throughout the country. Leaves small and narrow type and spiny branches bearing sickle shape one segmented cladodes and clusters of fusi form succulent tuberous root. In Sanskrit, *Shatamuli* means "she who possesses a hundred husbands". These tuberous roots after proper processing and drying are used as medicine in *Ayurveda*, with the name of *Shatamuli*. Asparagus is considered to be the main *Ayurvedic* rejuvenating female tonic for overall health and vitality. The reputed adaptogenic effects of asparagus may be attributed to its concentrations of saponins. Tuberous rootstocks are useful to cure dysentery and diarrhea. Tonic from tubers is used to save and increase hair. It is also used as jaundice, amenorrhea, diuretic, rheumatism and diabetes. (Hoque, 2008).

The solar tunnel dryer is one of promising option for drying various agricultural and agro-industrial products on large scale. Therefore, an attempt was made to studying the performance of the solar tunnel dryers using varying operating conditions was studied using shatavari roots.

Materials and Methods

Design of solar tunnel dryers

Total quantity of water in product, M_{tw}

$$M_{tw} = W_g \times \frac{Mi}{100}$$

Bone dry weight of material, W_{bd}

$$W_{bd} = W_g \times [1 - \frac{Mi}{100}]$$

Quantity of water to be evaporated, M_w

$$M_w = \frac{Wg\,(Mi - Mf)}{(100 - Mf)}$$

Drying rate, W_{dr}

$$W_{dr} = \frac{Mw}{td}$$

Total heat requirement, Q_T

$Q_T = Q_1+Q_2+Q_3$

$Q_T = W_{bd}. Cp (T_f - T_a) + M_{tw} x C_w x (T_f - T_a) + W_w X \lambda$

Collector area / Drying area, A_c

$A_c = \frac{QT}{Isc\ x\ \eta\ x\ Area\ receiving\ sunlight}$

Dimensions of solar tunnel dryer

For a semi- cylindrical shape of solar tunnel dryer, the appropriate dimensions of drying area are

Radius of solar tunnel dryer(m) = R

Diameter of solar tunnel dryer(m) = D

Area of semi spherical shaped solar tunnel dryer (m^2) A = π x R x L

Length of solar tunnel dryer (m) = L

Floor area of solar tunnel dryer, (m^2)

A = L x D

Design of north wall

Total area of transparent cover

(A_{tc}) = π x R x L

Area of protector (A_p) = 0.32 x A_{tc}

The arc width of cover through which energy is lost

$w = \frac{Ap}{L}$

The perimeter of STD (P) = π x R

Since, perimeter covers diametrical length (m) = dl

Therefore, arc width will cover diametrical length was calculated as,

$d_l = (d\ x\ w)/ P$

Height of protector (h_p) = $\sqrt{w^2 - dl^2}$

Design of chimney

Quantity of water evaporated, Mw

$M_w = W_i (\frac{Mi-Mf}{100-Mf})$

Quantity of air needed to absorb M_w kg of water, Q_a

$Q_a = (\frac{Mw\ X\ \lambda}{Ca\ X\ \rho a\ (Te-Ta)})$

Quantity of air needed to removed moisture in 40h, M_a

$M_a=\frac{Qa}{Wi}$

Draft produce, assumed height of chimney is 0.50 m

$D_1 = H \times g \times (\rho_a - \rho_e)$

The actual draft will be assumed as 25% of this draft, so

Actual draft $D_2 = 0.75 \times D_1$

Velocity of exist air through chimney, V

$V = \sqrt{2D_2 / \rho_e}$

Cross section area of chimney, A_{ch}

$A_{ch} = \frac{Q}{V} X k$

Diameter of chimney, Dc

$D_c = \sqrt{\frac{Ach \times 4}{3.14}}$

Development of solar tunnel dryers

Solar tunnel dryers were erected in the Department of Unconventional Energy Sources and Electrical Engineering ,Dr. PDKV Akola. The main components of the solar tunnel dryers was foundation, foundation pipes, hoops, end frame, lateral support, cover material, drying trolleys, north wall, chimney and exhaust fan. The technical specifications of solar tunnel dryers for drying of shatavari roots are listed in following table.

Table 1 : Technical specifications of solar tunnel dryers

Specifications of solar tunnel dryers			
Sr. No.	**Components**	**Specifications**	
		STD-PE	**STD-PVC**
1	Length of solar tunnel dryer, m	18	12
2	Height of solar tunnel dryer, m	2.2	2.2
3	Diameter of solar tunnel dryer, m	4	3.5
4	Floor area of solar tunnel dryer, m^2	72	42
5	Area of hemicylindrical shape of solar tunnel dryer, m^2	125.67	75.60
6	Covering material	Polyethelene sheet 200 micron	PVC film 2 mm
7	UV stability Period	5 years	3 years
8	Height of north wall, m	1.5	1.35
9	Length of north wall, m	18	12
10	Number of chimney	3	2
11	Diameter of chimney, m	0.25	0.25
12	Height of chimney, m	0.50	0.50

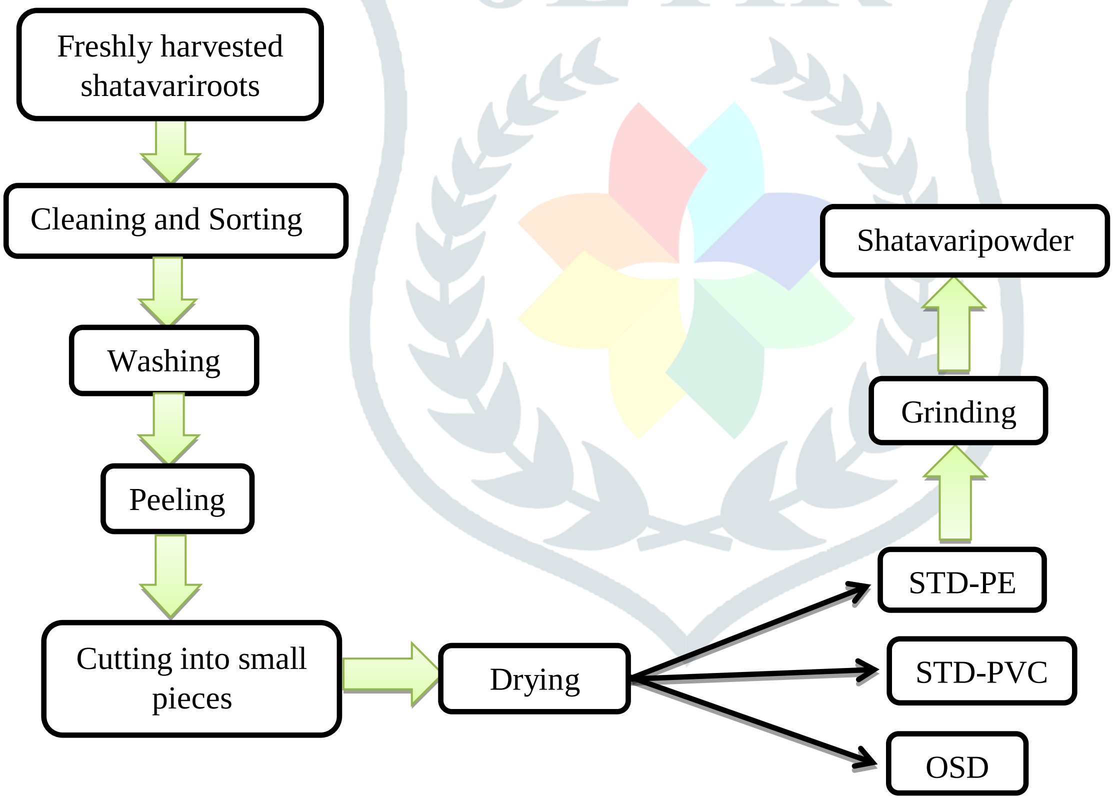
13	Tray size, m	1.10 x 0.62 x 0.03 m	1.10 x 0.62 x 0.03 m
14	Number of trays	8 trays per stand	8 trays per stand
15	Number of stands	8	5
16	No. of Doors	1	2
17	Door size,m	1.95 x 0.90 m	1.95 x 0.90 m
18	Fan	1	-

No load testing of solar tunnel dryers

The variation of temperature, relative humidity and air velocity in the solar tunnel dryers with corresponding ambient temperature, relative humidity and solar radiation were recorded to evaluate the performance of solar tunnel dryers. The test was conducted between 9.00 to 18.00 h.

Performance evaluation of Solar Tunnel Dryers

Procedure for drying of Shatavari



Full load testing of Solar Tunnel Dryers

In full load test the roots of Shatavari is spread over the perforated aluminum tray in thin layer. The experiment was conducted after harvesting of Shatavari. The initial weight of the samples were recorded. The samples were weighed regularly at an interval of 1.00 h and simultaneously the temperature, relative humidity, solar radiation and wind velocity was recorded. The drying was conducted between 9.00 to 18.00 h daily.

Study of drying characteristics

Determination of moisture content

$$M.C.(wb)\% = \frac{(W_1 - W_2)}{W_1} \times 100 \quad M.C.(db)\% = \frac{(W_1 - W_2)}{W_2} \times 100$$

Determination of moisture ratio

$$\text{Moisture Ratio (M.R.)} = \frac{(M - M_e)}{(M_0 - M_e)}$$

Determination of drying rate

$$\text{Drying rate } (D_R) = \frac{\Delta W}{\Delta t}$$

Drying efficiency (ŋ)

$$\eta_{\text{drying}} = \frac{Whfg}{\text{IST Aec}}$$

Sensory evaluation and color determination of dried product

Sensory attributes of shatavari powder including appearance, taste, texture, aroma, overall acceptability were evaluated to determine optimum point of drying quality of product. The evaluation was conducted by using a 9-point hedonic scale (1= dislike extremely, 9= like extremely) by 10 panelists selected by staff and students.

Surface color was determined using HunterLab (HunterLab – LabScan XE, Hunter Associates Laboratory Inc., Reston, VA, www. hunterlab.com), which includes lightness and chroma saturation.

Result and Discussion

Performance evaluation of solar tunnel dryers

No load testing of solar tunnel dryers

Experiments were conducted inside the two solar tunnel dryers simultaneously to know about the maximum temperature attained. Under no load testing observations were taken for the measurement of solar insolation, ambient temperature, ambient relative humidity and relative humidity inside the dryers.

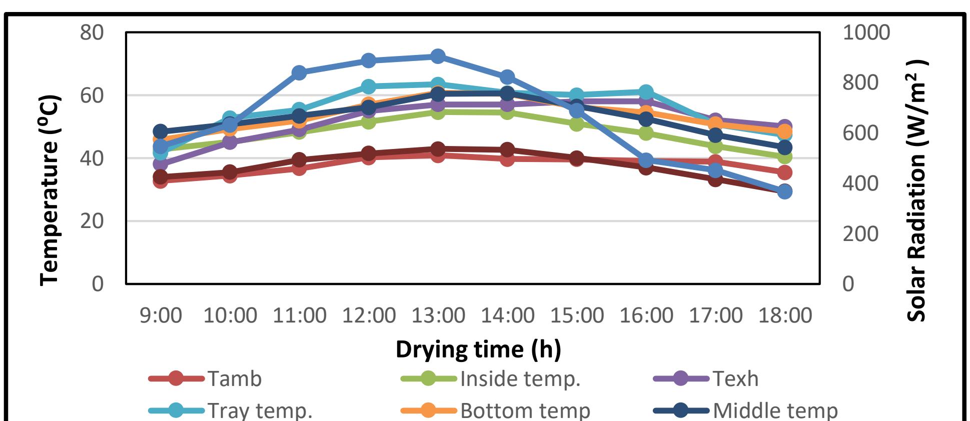


Fig 3. Average temperature variation during no load test inSTD-PE

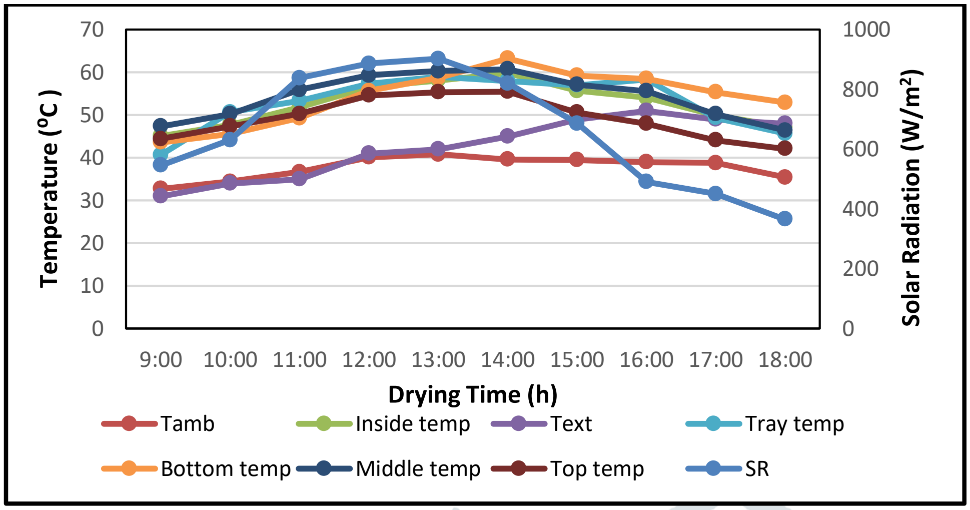


Fig 4. Average temperature variation during no load test in STD-PVC

Full load testing of solar tunnel drying system

During full load testing the sample of Shatavari roots of known moisture content was loaded in single layer on trays trolleys in solar tunnel dryer. The drying of the samples was continued till the moisture content reached to 9% (wb). The drying experiments were carried out on typical sunny days in the month of April 2021. The results obtained from the drying experiment in solar tunnel dryer was compared with open sun drying.

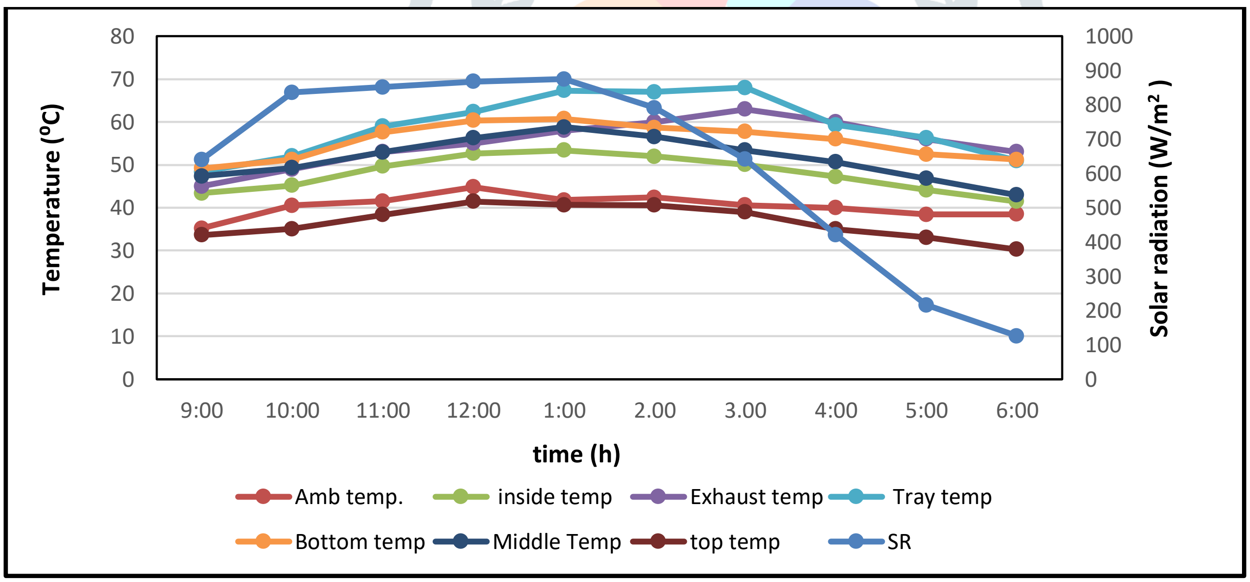


Fig 5. Average temperature variation during full load test in STD-PE

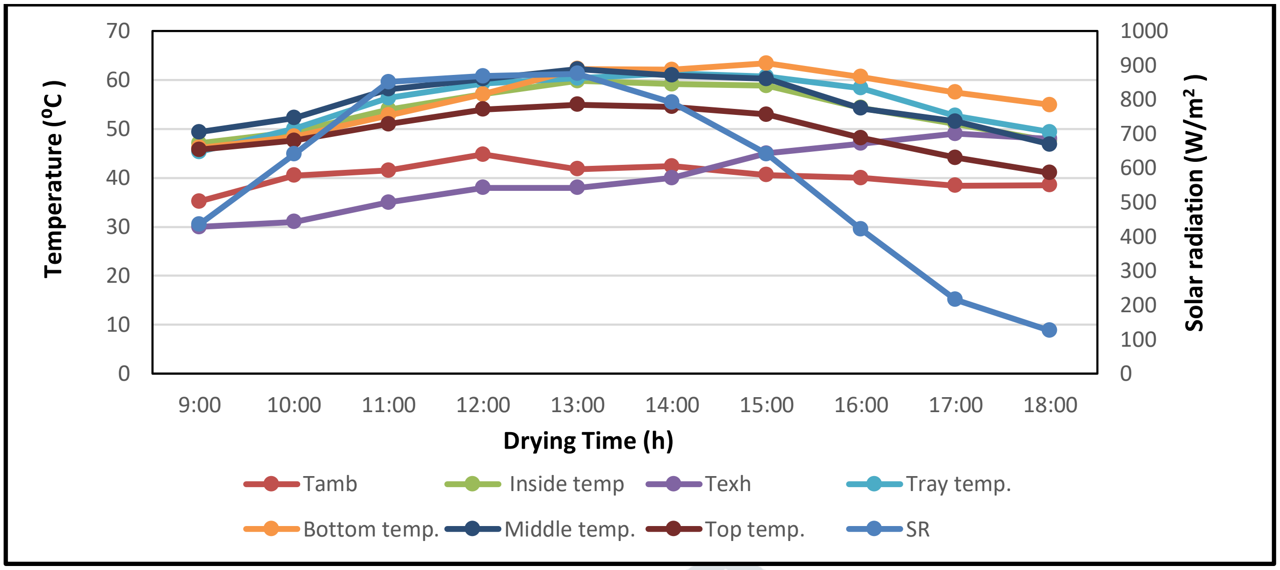


Fig 6. Average temperature variation during full load test in STD-PVC

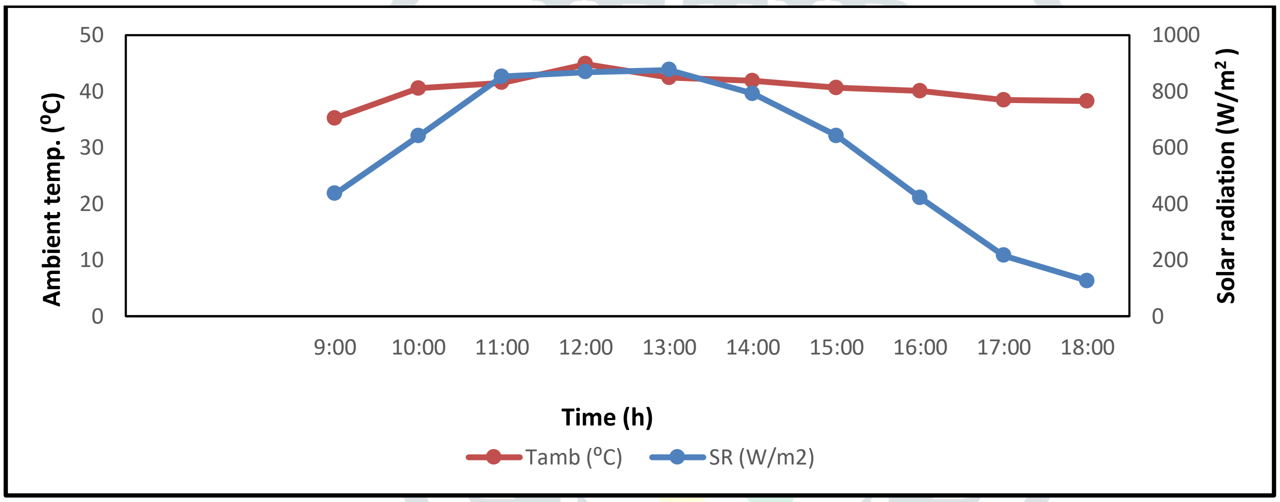


Fig 7. Variation of temperature and solar radiation of open sun drying under full load testing

Study of drying characteristics of Shatavari in solar tunnel drying system

The drying characteristics of Shatavari and Pashanbhed in solar tunnel dryers were studied and compared with open sun drying. The different drying characteristics in terms of moisture content in percent (db), drying rate (gm /100 gm bdm min) and moisture ratio were studied.

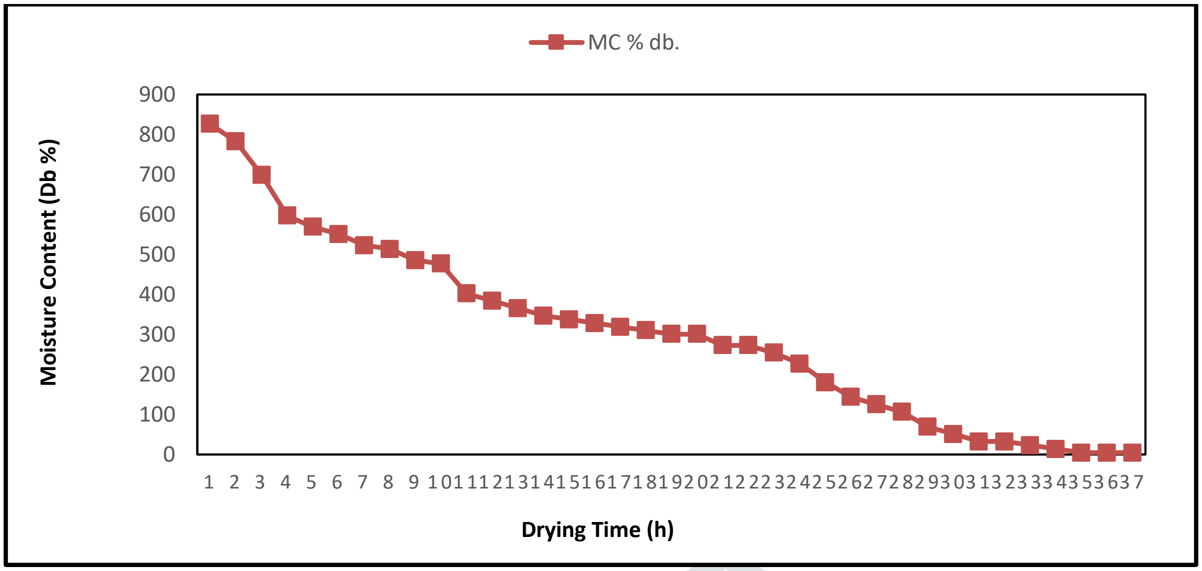


Fig 8. Variation in moisture content of Shatavari in STD-PE with respect to drying time

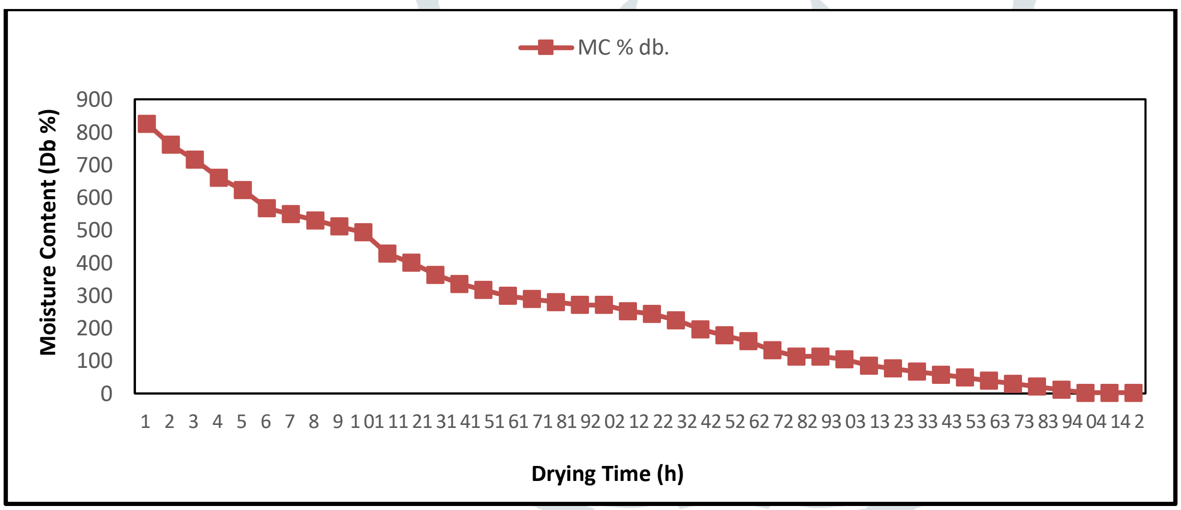


Fig 9.Variation in moisture content of Shatavari in STD-PVC with respect to drying time

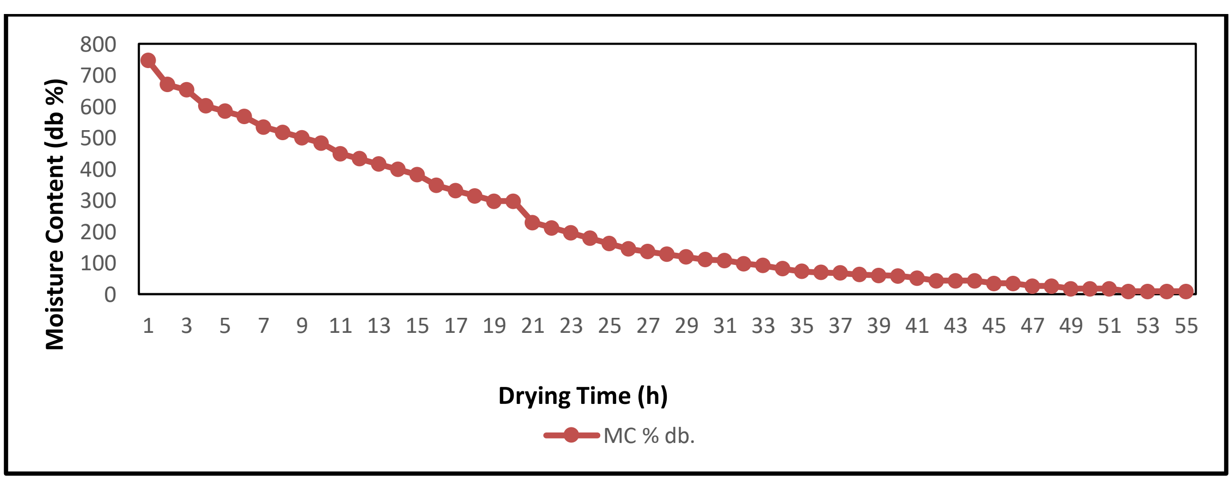


Fig 10. Variation in moisture content of Shatavari in open sun drying with respect to drying time

Determination of colour value for Shatavari Powder

Table 2 : Colour value testing for Shatavari powder

Sample	Drying Method	L	a	b
Shatavari Powder	STD-PE	82.84	1.02	10.65
	STD-PVC	83.33	0.99	10.02
	OSD	80.47	1.24	12.91

Determination of drying efficiency of solar tunnel dryers

The drying efficiency of solar dryer is the ratio of heat gained to the heat input. The heat input will be calculated by considering total solar radiation incident in aperture area of solar collector during total drying hours in day. (Prasad *et al.* 2006)

Drying efficiency calculation for STD-PE

$$\eta\ (\%) = \frac{Heat\ gained}{heat\ input} = \frac{991807.2}{5834160} \times 100$$

$$= 17\ \%$$

Drying efficiency calculation for STD-PVC

STD-PVC OSD **OSD**

$$\eta\ (\%) = \frac{\ }{heat\ input} \quad \frac{592526}{4010679.491}$$

$$= 14.77\ \%$$

Conclusion

The Solar tunnel drying system maintains nearly 60^0C temperature therefore it is used for drying of Shatavari.At no load test, the maximum temperature and relative humidity during day time in STD-PE was 54.58°C and 25 %, in STD-PVC it was 57°C and 26 % and in OSD it was 40.8°C and 26% respectively. In full load test maximum temperature in STD-PE was 53.4°C and in STD-PVC it was 59.8 °C and in OSD was 44.8°C in the month of May.The time required for drying of Shatavari sample in STD-PE was found to be 36 h. In STD-PVC it took 41h and 54 h in open sun drying. The drying time for Shatavari was found less in STD-PE than STD-PVC & highest in OSD.The efficiency of STD-PE was 17 % and efficiency of STD-PVC was found to be 14.77 %.On the basis of economic analysis payback period for STD-PE were found to be 10 months 27 days and for STD-PVC it was 7 months 23 days for Shatavari roots drying.

References

Aggraval, K. R., M. M. Sharma, A. K. Sharma 2010. Indirect solar drier with electric backup system for quality hill products. J. Natural Resources 1: 88-94.

Basunia, M.A., Al-Handali, H.H., Al-Belushi, M.I., Rahman, M.S. and Maghoub, O. 2012. Development and performance evaluation of a solar tunnel date dryer in Oman. *Journal of Agricultural and Marine Sciences* 17: 21-31.

Chakraverty, A. 1988, Post-harvest technology of cereals, pluses and oil seed. New Delhi, Oxford and IBH Pub. Co. Pvt. Ltd., PP. 33-39.

Chavan, B. R., A. Yakupitiyage and S. Kumar, 2011. Drying performance, quality characteristics, and financial evaluation of Indian Mackerel (Rastrilliger Kangurta) dried by a solar tunnel dryer. Thammasat Int. J. Sc. Tech. 16(2).

Goyal, R.K., A.R. P. Kingsly, M.R. Manikanthan, S.M. llyas, 2007. Mathematical modelling of thin layer drying kinetics of plum in a tunnel dryer. J. Food Engineering 79: 176-180.

Gurlek, G., N. Ozbalta and A. Gungor, 2009. Solar tunnel drying characteristics and mathematical modelling of tomato. J. Thermal Science and technology 29(1): 15-23.

H.P. Garg, R. Kumar,(2010),Studies on semi-cylindrical solar tunnel dryers: thermal performance of collector", Applied Thermal Engineering 20, 115-131.

Jose, K. P. and C. M. Joy, 2009. Solar tunnel drying of turmeric (curcuma longa linn. Syn. C. Domestica Val.) for quality improvement. J. of Food Processing and Preservation, 33(1): 121-135.

Kalbande, S.R. and G. R. More, 2008. Assessment of energy requirement for cultivation of kharif and rabi sorghum. Karnataka J. Agricultural Sciences 21(3): 416-420.

M.A. Hossain,, J.L. Woods, B.K. Bala,(2005) Optimisation of solar tunnel drier fordrying of chilli without color loss, Renewable Energy 30,729-742.

M.M.I. Chowdhurya, B.K. Balaa, M.A. Haque,(2011),Energy and exergy analysis ofthe solar drying ofjackfruit sssleather,biosystem engineering IIO,222-229.

Sevda, M. S. and N. S. Rathore, 2007. Studies on semi-cylindrical solar tunnel dryer for drying Di-basic calcium phosphate. Agricultural Engineering International: The CIGR Ejournal IX.