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Utilization of Solar Tunnel Dryer for Drying of Fodder Crop

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Abstract: ***A solar tunnel dryer of 200 kg capacity was utilized for drying of fodder crop. The dryer is having size 14.24 × 3.34 × 2 m (L × W × H) with G.I. pipe frame structure was covered with UV stabilized 200 µm transparent sheet. The solar tunnel dryer consisted of solar collector section and drying section. In drying section 8 trays with mesh bottom in which 4 trays having step like structure of size 3 × 1.2 × 1.1 m and 4 trays of size 3 × 1.2 × 0.6 m were used to facilitate the loading and unloading of the products. For ventilation 4 chimneys having 0.30 m diameter and 0.70 m height were provided with 2 AC exhaust fans. A provision of north wall of size 14.24 × 1 m was provided to minimize heat losses. At no load condition, temperature inside the solar tunnel dryer with respect to time achieved its peak value at absorber plate was found to be 52.1 ^{0}C at 13:05 of the day whereas the atmospheric temperature was about 36.1 ^{0}C. The drying time required for fodder crops dried from moisture content of 80-90 % (w.b) to attain safe moisture content of 8-10 % (w.b) is 6.5-8 hours and 16-18 hours in solar tunnel dryer and open sun drying respectively. The results showed that the drying rate of fodder crop under solar tunnel dryer was found to be improved during initial phase of drying due to higher moisture diffusion.***

1. Introduction

Fodder has long been an important source of food for cattle all over world. Fodder crops are cultivated plant species those are utilized as livestock feed. Fodder crop may be classified as either temporary or permanent crops. The former are cultivated and harvested like any other crop. Good planning is required to feed the cattle during dry season. A lot of fodder can be conserved and be used to feed the animals between January and May when there is severe fodder shortage. The entire crop residue can be collected and conserved well for use as fodder in the dry season. Specifically, fodder is used as animal feed for domesticated livestock such as cattle, sheep, horses, and pigs.

Drying is mass transfer process consisting of the removal of water or another solvent by evaporation from a solid, semi-solid or liquid. Basically, drying can be done by two process viz. natural drying and artificial drying which is based on source of energy. Natural drying takes place under the influence of Sunlight and wind and is of three types viz. Sun, solar and shade drying. In natural drying there is no control over temperature, air flow and humidity. In artificial drying, these conditions are well controlled by using dryers. The various types of artificial drying are Freeze drying, Sun drying, Kiln drying, Belt-trough drying, Fluidized bed drying, Spray drying, Solar drying.

Drying of agricultural products is one of the most attractive and cost effective application of solar energy. A numerous types of solar dryer have been designed and developed. There are four types of solar dryer viz. direct solar dryers, indirect solar dryers, mix-mode dryers and hybrid solar dryer. The solar tunnel dryer is a polyhouse dryer suitable for drying most of the food crops. It consists of a tunnel type semi-cylindrical drying chamber provided with windows to allow the ambient air to enter the dryer. An exhaust fan is provided with chimney to evacuate the moist air from the dryer. A door is also provided to facilitate easy handling of the produce. The maximum temperature of the air inside the dryer was observed to be 55-60 ^{0}C. The solar dryer can also be used for drying chillies, grapes, sapota, mango, fish, amla, fodder etc.

In present contest, the conventional method of fodder drying was open Sun drying. The open Sun drying of fodder results in contamination of product due to dust, insects etc. The open Sun drying requires large time as well as it is an uncontrolled temperature drying. The conventional method of fodder drying causes the loss of material, nutrients and quality of the product during the drying and hence reduces cost of final product. It is necessary to dry the product in close chamber with control conditions, to reduce the processing losses during the drying and retain the quality of dried product. The solar tunnel dryer may be the best viable option for drying of fodder using the abundantly available free solar energy in the region. The utilization of solar dryer for drying of fodder eliminates the process losses with high rate of drying in controlled condition.

2. Materials and Method

The schematic view of solar tunnel dryer for fodder drying is shown in figure 1. The different parts of dryer are air inlet, absorber area, drying tray, transparent dome, G.I. frame and chimney for discharging exit air. The North wall of solar drying system is made of thermocole with dull black paint is used as an absorber. The door is provided to the dryer for easy loading and unloading of product. A dome is then provided for the resting of the transparent thick plastic sheet. The UV polytheen of 200 gauges is used to collect the solar energy heat. A part of heated air will pass directly through the material bed and the remaining hot air will pass along the bottom of each layer. This heated air will absorb moisture from the wet fodder while it is passing through the bottom of the tray of independent layers. Finally, the air will be discharged from the dryer through the chimney at the elevated location. The diameter of chimney is 0.30 m and the height of chimney is 0.70 m made of light sheet metal. The overall dimensions of the unit are 14.24 × 3.34 × 2 m.

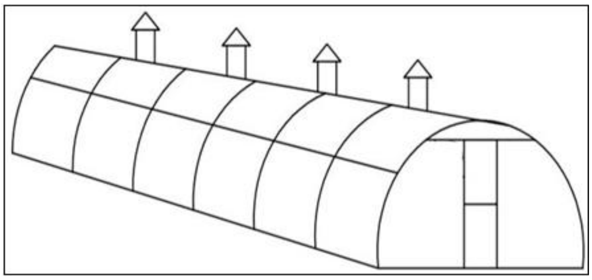

Figure 1: Schematic view of solar tunnel dryer

Table 1: Details of solar tunnel dryer used for drying of fodder crop

Sr. No.	Parameters	Value
1.	Solar collector area, A_c	47.56 m^2
2.	Length of dryer, L	14.24 m
3.	Width of dryer, W	3.34 m
4.	Number of trays	8
5.	Vent area	5.823 m^2
6.	Vent length	14.24 m
7.	Vent height	0.8 m
8.	Diameter of chimney, d_1	0.30 m
9.	Height of chimney, H	0.70 m

Plate 1: Outside view of Tunnel Dryer

Plate 2: Inside view of Tunnel Dryer

Performance evaluation of solar tunnel dryer for drying of fodder crop

The performance was carried by conducting the no load test for testing designed parameters and Load test in comparison with open sun 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. The various temperatures recorded are,

1) Ambient temperature (T_1 °C)
2) Outlet air temperature (T_2 °C)
3) Absorber plate temperature (T_3 °C)
4) Temperature above the 1st tray (T_4 °C)
5) Temperature above the 2nd tray (T_5 °C)
6) Temperature at the bottom of chimney (T_6 °C)

Similarly, relative humidity recorded at various places is,

1) Relative humidity of the atmosphere (RH_1 %)
2) Relative humidity at exit of the chimney (RH_2 %)
3) Relative humidity above the 1st and 2nd tray (RH_3 %)

Load Test: Performance evaluation of solar tunnel dryer for drying of fodder was carried out. Freshly available mixed fodder was taken for drying. The fodder samples were taken and washed thoroughly. After that two samples were selected and weighed before loading. The weight reduction of the sample was taken at 1-hour interval by using weight balance. Initial moisture content of fodder sample was calculated using standard hot air oven method.

Moisture Content

The percentage moisture content was determined by using following formula,

$$MC_{(w.b.)}\ \% = \frac{W1-W2}{W1} \times 100$$

$$MC_{(d.b.)}\ \% = \frac{W1-W2}{W2} \times 100$$

Where, W_1 = weight of sample before drying, gram

W_2 = weight of dried sample, gram

Drying Rate

The drying rate (g/h/100g of dry weight) of fodder sample during drying period was determined as follows,

$$\text{Drying rate (D.R.)} = \frac{\Delta W}{\Delta T}$$

Where, ΔW = weight loss in one hour interval (g/100g of dry wt)
Δ T = difference in time reading (h)

The drying was carried out by loading the weighted fodder in dryer from morning 8:00 am to 17:00 pm. The fodder was dried up to the final moisture content of 14.73 % (db). The similar procedure was adopted for drying of fodder sample in open sun drying. The drying time required for drying the fodder sample from IMC to 14 % (d.b.) in solar tunnel dryer and under open sun drying condition was critically observed.

Moisture Ratio

The Moisture ratio of fodder was computed by using the initial moisture content (IMC) and equilibrium moisture content (EMC)

$$\text{Moisture Ratio} = \frac{M-Me}{Mo-Me}$$

Where,
M = Moisture content (d.b.), %
Me = EMC, (d.b), %
Mo = IMC, (d.b), %

The EMC for fodder was considered as 12 % (d.b.) Drying tests of fodder sample under solar tunnel dryer and open sun conditions was carried out.

3. Results and Discussion

Microclimatic study for No load test

The dryer was tested without loading fodder in the dryer and different atmospheric parameters were measured like temperature, relative humidity and solar intensity at every one-hour interval. The change in temperature, relative humidity, and insolation with respect to time at various locations are depicted in Figure 2 and Figure 3.

Figure 2, revealed that, temperature inside the solar tunnel dryer at 13.05 was achieved its peak value at absorber plate was found to be 52.1 ^{0}C whereas the atmospheric temperature was about 36.1 ^{0}C. The temperature at upper tray and lower tray was found to be 55.4 ^{o}C to 50.4 ^{o} C and at the exit of the chimney it was 44.7 ^{0}C. According to the solar insolation the drying time varied. The atmospheric relative humidity was varied from 46.3 % to 74.9%, whereas at upper tray it varied from 39.7 % to 65.6 %.

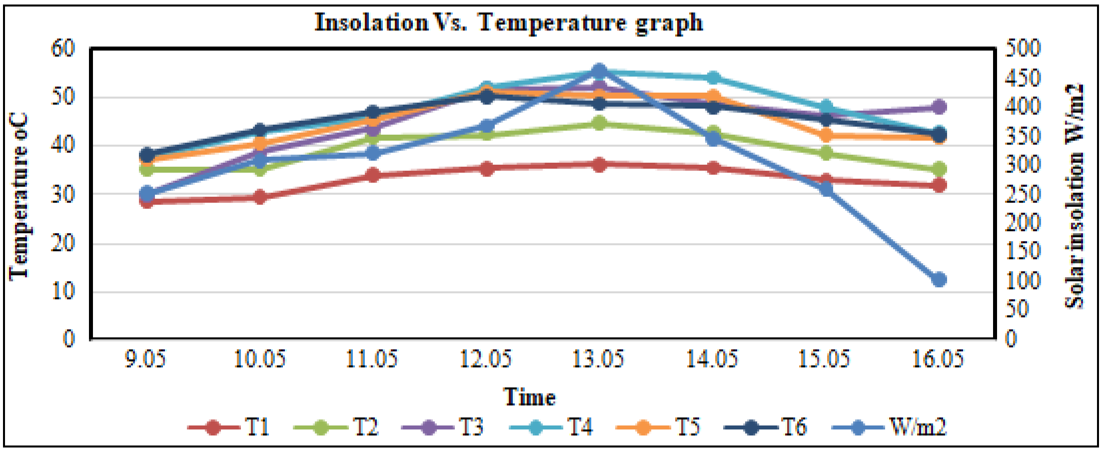

Figure 2: Variation of Temperature along with solar Insolation during No load test

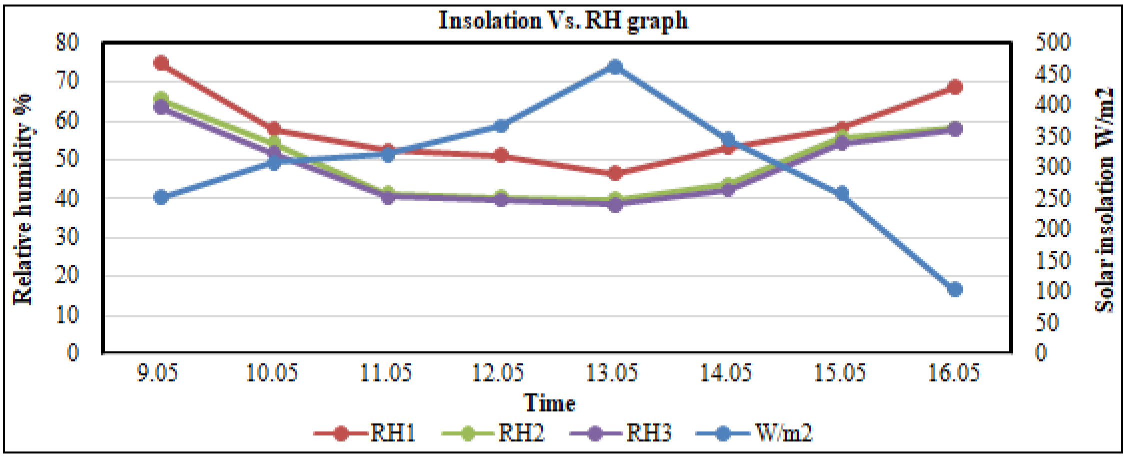

Figure 3: Variation of Relative Humidity along with solar Insolation during No load test

Microclimatic Study and Moisture Reduction for Load Test

The load test was taken for the fodder. Figure 4 and Figure 5 shows insolation, temperature and relative humidity variations during load test and Figure 6, 7 and 8 shows the moisture reduction, drying rate and moisture ratio for the load test. Figure 4, shows that as insolation increased temperature inside dryer also increased. Insolation increased from morning to afternoon and attains its peak value at 13 noon of the day and after that it again reduced. The insolation varies from 134 W/m^2 to 374 W/m^2. The peak value of insolation is 374 W/m^2 and the corresponding atmospheric temperature was 36.9 °C while maximum temperature attained inside the dryer was 54.3 °C. The atmospheric relative humidity varied from 34.4 % to 64.6 % and at upper tray it varied from 33.6 % to 62.2 %.

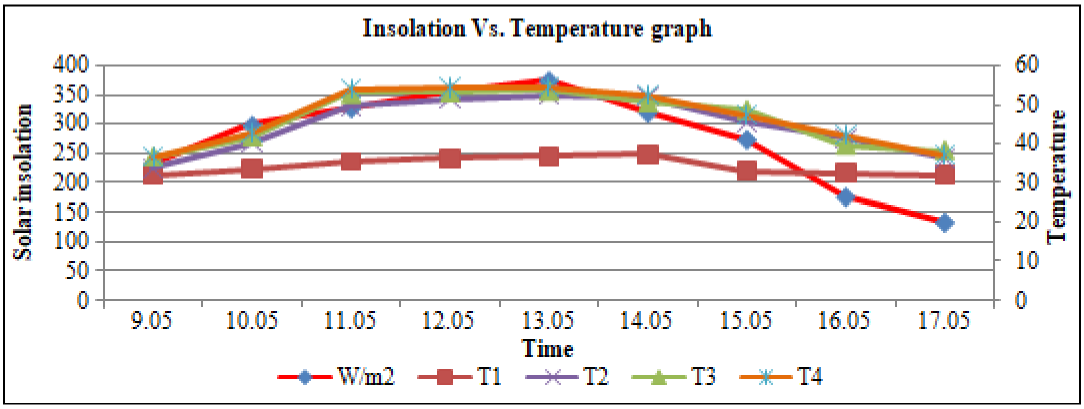

Figure 4: Variation of Temperature along with solar Insolation during Load test

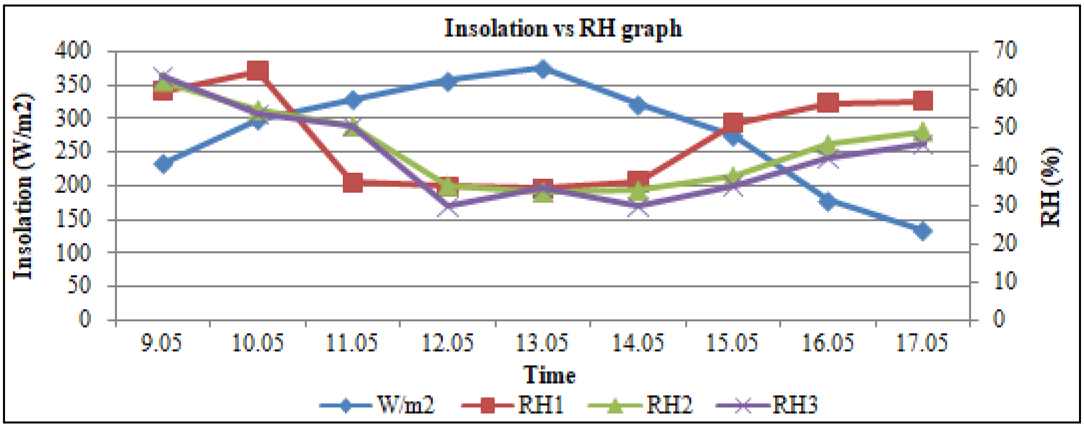

Figure 5: Variation of Relative Humidity along with solar Insolation during Load test

The moisture content of the fodder reduced from 176.42 % (d.b.) to 14.47 % (d.b.). The moisture was reduced rapidly at the beginning and later drying rate was decreased. Figure 6, shows that the moisture content decreased, as the time elapsed. The drying was completed in 8 hrs.

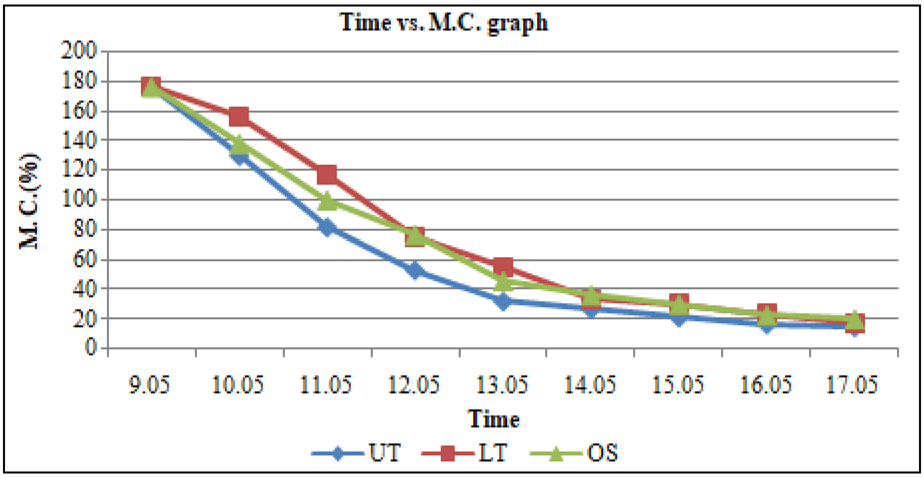

Figure 6: Reduction in moisture along with time for Load test

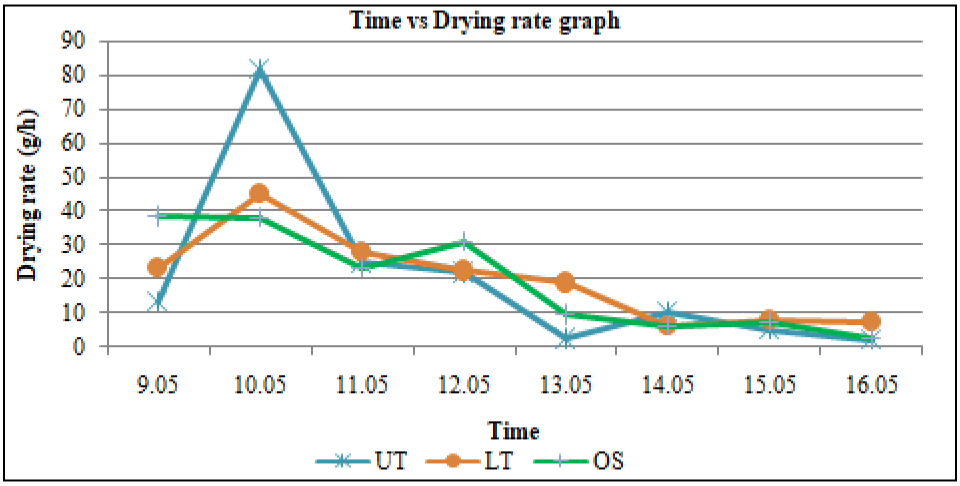

Figure 7: Drying rate for Load test

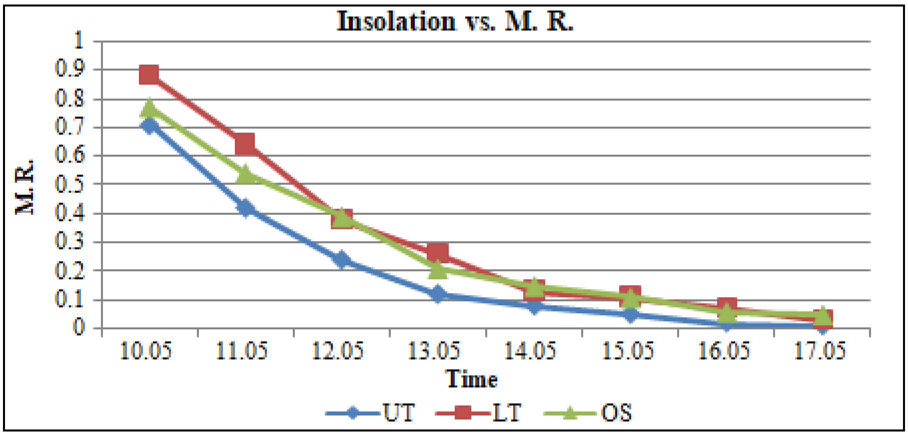

Figure 8: Moisture ratio Variation along with time for Load test

4. Conclusions

At no load condition, temperature inside the solar tunnel dryer with respect to time achieved its peak value at absorber plate and was found to be 52.1 ^{0}C at 13:05 of the day whereas the atmospheric temperature was about 36.1 ^{0}C. The drying time required for fodder crops dried from moisture content of 80-90 % (w.b) to attain equilibrium moisture content of 8-10 % (w.b) was 6.5-8 hours in solar tunnel dryer and 16-18 hours in open sun drying. For drying of fodder, drying rate was higher for solar tunnel dryer compared to open sun drying. The results showed that the drying rate of fodder crop under solar tunnel dryer was found to be very high during initial phase of drying due to higher moisture diffusion.

For utilization of solar tunnel dryer for drying of fodder to reduce the process heat losses with high rate of drying in a controlled condition, solar tunnel dryer was found as viable option. In drying of fodder, solar tunnel dryer required less drying time followed by open sun drying. The study concluded that colour, texture and overall acceptability did not vary significantly. There was a good relation between variation of moisture content and drying rate with drying time in Solar tunnel dryer followed by open sun drying for fodder.

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