DESIGN AND FABRICATION OF SOLAR TUNNEL DRYER FOR COPRA APPLICATION

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Abstract

A semi-cylindrical forced convection type solar tunnel dryer (STD) was designed and commissioned at M/s Miraj Products Pvt. Ltd., Nathdwara for drying processed tobacco. Essentially it is based on the mixed mode with direct and indirect type of heating mechanism i.e. the heated air from different solar flat plate collectors is passed through drying cabinet. At the same time, the drying cabinet absorbs solar energy directly through the transparent walls and roofs. It consists of 16×3.75 m^2 area, tunnel equipped with 12 solar flat plate collectors of 2 m^2 each propelled with 2 exhaust fans of 1 kW capacity placed on both ends of the tunnel. The dryer was tested at no-load and full-load conditions. During no-load, without flat plate collectors, temperatures inside the dryer were about18-20°C higher than the ambient temperature during summer day-light, where as in no-load with flat plate collectors, it was about 30°C higher than the ambient temperature. A batch of processed tobacco of 500 kg with an initial moisture content 138% d.b. were successfully dried in full load condition to have final moisture content of about 8.7% d.b. in 8 h. It has been observed that STD has many other advantages i.e. getting rid of toxicant gas to labours during opening drying due to lime presence in material, avoidance of product expose to fly contamination and dust concentrations etc.

Keywords*: Solar tunnel dryer (STD), natural convection, forced convection, mixed mode.*

1. Introduction

Solar drying is a continuous process where moisture content, air and product temperature change simultaneously along with the two basic inputs to the systems: the solar insolation and inlet air at ambient temperature. The drying rate is affected by ambient climatic conditions. This includes temperatures, relative humidity, sunshine hours, solar insolation, wind velocity, frequency and duration of rain showers during the drying period etc. (Sevda, 2003). A solar tunnel dryer is essentially a poly house having tunnel like framed structure covered with ultra-violet (UV)-stabilized polythene sheet, where agricultural and industrial products could be dried under at least partially control environment, in which loading and unloading is quite easy (Sevda, 2007). A mixed-mode solar dryer allows the heated air from a separate solar collector to pass through a grain bed, and at the same time, the drying cabinet also absorbs solar energy directly through the transparent walls and roof. The performance evaluation of such a dryer revealed that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most time of the day light (Bukola, Bolaji and Ayoola, 2008).

2. Design of solar tunnel dryer

The mixed-mode type forced convection solar tunnel dryer shown in Fig.1was designed to dry 0.5 t of processed tobacco from 138% d.b. to 11% d.b. moisture content with flat plate air heating collectors, a tunnel drying unit and

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blowers to provide the required air flow rate over the product. The design parameters were decided on the basis of amount of moisture to be removed, specific gravity of material, and flow rate required for removing moisture in stipulated time.

Fig.1. Frame work of solar Tunnel dryer

The drying unit was covered with transparent UV stabilized semi-transparent polythene sheet of 2×10^{-4} m thickness. Low cost materials possessing high rigidity, long life and superior thermal characteristics were used for construction of floor, super structure and solar collectors. Cement concrete floor was painted black for better absorption of solar radiation. 5 cm thick glass wool insulation was provided to reduce heat loss through the floor. It was based on the theoretical calculation for critical insulation thickness for this dryer. The orientation of solar tunnel dryer was in east-west direction, so the sun covers the south side and the north side of the dryer act as an absorber. The north wall has a metallic cover of height of 1.5 m and glass wool sandwich in metallic cover for insulation. The products to be dried were placed in a thin layer on a stainless steel wire screen trays that are sliding on ball bearing for easy loading. Efforts were made for continuous and automatic loading of material inside the dryer. Various strategies for increasing work efficiency of system were developed during test of the system in actual use, like the loading of product in layer of constant thickness by the hopper, below the hopper the trays moves with constant speed by the motor, and trays can easily loaded in dryer by sliding on the ball bearing on rail from outside of the dryer.

The salient features of the solar tunnel dryer commissioned at the Sri Jayasakthi Edible Oil Pvt. Ltd., Salem were as follows, semi-cylindrical poly house having base area of 8 m×3 m and with maximum ceiling height of 2.5m, the metallic frame structure covered with polythene sheet. Incoming air through bottom opening of 100mm and turbo fan as been placed on the top surfaces to provide the fresh air continuously to the dryer. The dryer was loaded with 1.5 tonne capacity of copra and initial moisture content of copra deducted as 53.2%. at the start of experiment. The uniform speed of inlet velocity varied between 1.5m/s to 3m/s. Fig.2 shows the fully Loaded copra on the solar tunnel dryer.

3. Experimental analysis of solar tunnel

The analysis of solar tunnel for four consecutive days is tabulated in Table-1 to Table-4.

Table .1 Analysis of solar tunnel on day-1

TIME (Hr)	Moisture (%)	Tamb (°c)	Tdryer (°c)	Humidity	Solar Constant
9AM	55.68	28.5	38.5	51	362
10AM	53.24	29	41.5	53	436
11AM	51.72	31.2	45.7	56	512
12NOON	50.06	33	49.2	59	635
1PM	48.46	33.5	52.7	61	729

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2PM	46.91	32.7	51	64	752
3PM	44.31	31	49.3	61	678
4PM	42.37	30.5	47.2	60	537
5PM	40.39	30	46.8	58	478

Fig.2. Fully Loaded copra on the solar tunnel dryer

Table .2 Analysis of solar tunnel on day-2

TIME (Hr)	Moisture (%)	Tamb (°c)	Tdryer (°c)	Humidity	Solar Constant
9AM	36.81	28	38.2	53	346
10AM	34.12	27.6	40.1	55	418
11AM	32.37	29	41.4	58	497
12NOON	30.45	30.8	46.2	63	587
1PM	28.97	31.5	47	65	693
2PM	26.37	32	50.9	68	712
3PM	24.29	31.2	50.1	64	643
4PM	22.17	30.6	48.7	62	502
5PM	20.13	30.2	46.9	59	451

Table .3 Analysis of solar tunnel on day-3

TIME (Hr)	Moisture (%)	Tamb (°c)	Tdryer (°c)	Humidity	Solar Constant
9AM	17.29	29.1	40.2	52	353
10AM	16.14	30.7	42.8	55	425
11AM	15.31	31	45.2	57	504
12NOON	14.98	32.4	47.9	60	627
1PM	13.21	33.6	51.3	62	709
2PM	12.98	34	55.2	65	721
3PM	11.71	32.7	54.3	61	667
4PM	10.35	32.1	51.4	59	503
5PM	9.65	31.5	49.8	56	452

Table .4 Analysis of solar tunnel **on day-4**

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TIME (Hr)	Moisture (%)	Tamb (°c)	Tdryer (°c)	Humidity	Solar Constant
9AM	7.86	28.1	38.6	52	342
10AM	6.97	28.7	39.1	54	407
11AM	6.57	29.4	41.6	57	478
12NOON	6.41	31.3	44	59	557
1PM	6.38	32.3	48.6	63	663
2PM	6.30	33.4	53	68	714
3PM	6.24	31.64	51	65	621
4PM	6.20	30.9	49.2	63	497
5PM	6.15	30.4	48	61	447

4. Results & discussions

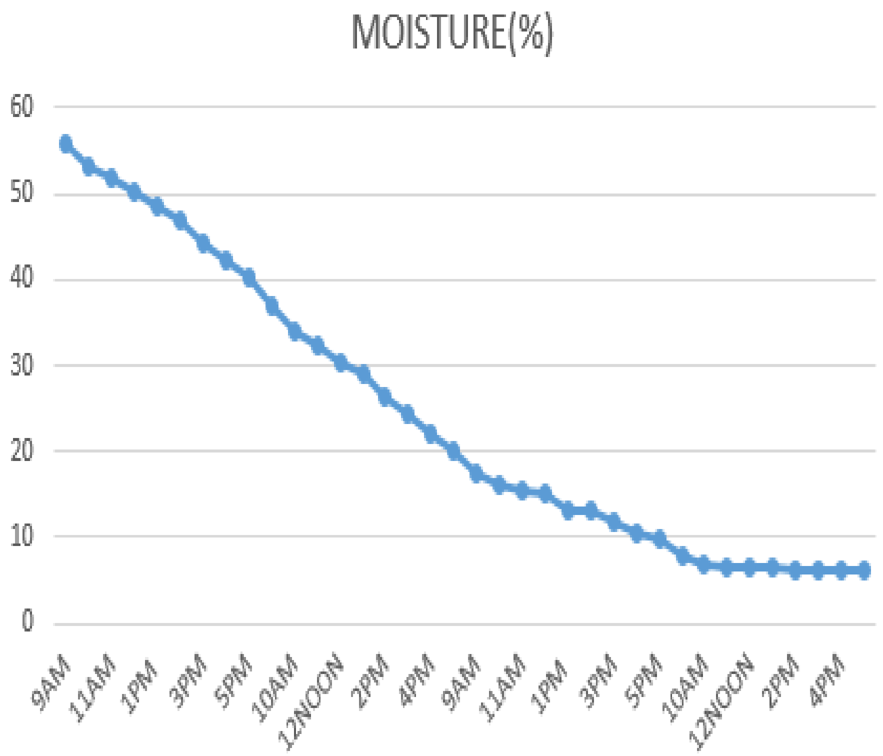

Fig.3. Time vs Moisture content

Fig.3 shows that the moisture content varied with the time. The Initial moisture content at the copra is 55.6% and its end to final moisture content of 6.15%. The Maimum moisture level reduced during the initial three days compared with final day and moisture remain constant after the maximum reduction of water from it.

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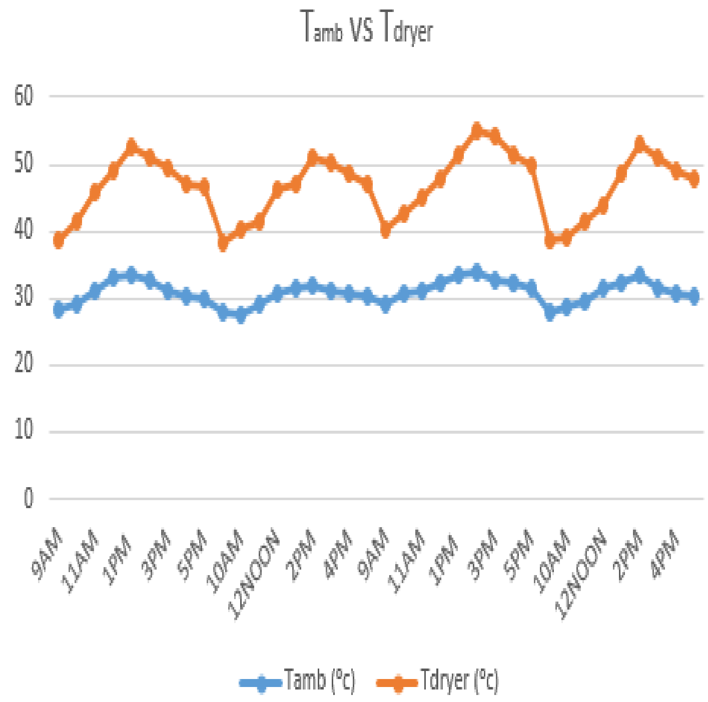

Fig.4. Time vs Ambient temperature and Dryer temperature

Fig.4 shows that the variation of ambient temperature and dryer temperature. The maximum ambient temperature of 34°Cattained during 2pm and maximum dryer temperature of 55.2°C. By the comparison of ambient temperature and dryer temperature there are 15°C to 20°C temperature varies.

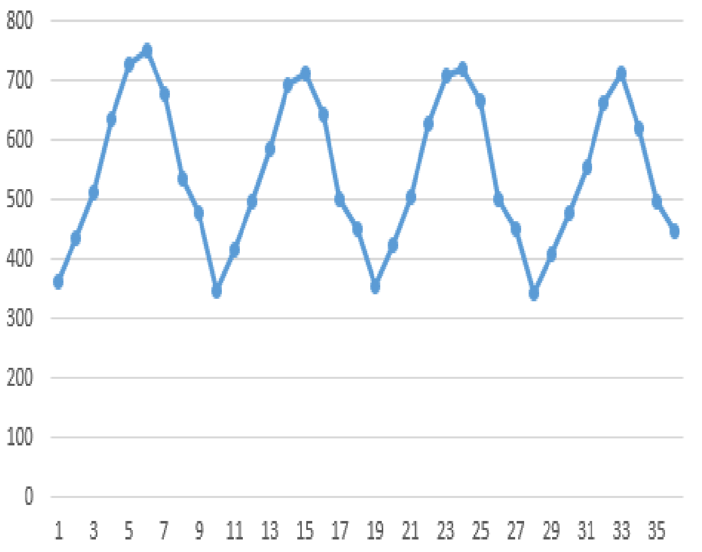

Fig.5. Time vs Solar constant

Fig.5 shows that the variation of time and solar constant. The maximum solar constant of 752W/m2 attained during the peak hour. Based on the maximum solar constant the temperature

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also increased and drying time for copra is decreased. The quality of sun dried and solar tunnel dried copra is tabulated in Table.5 and Table.6 respectively.

Table .5 Sun Dried Copra Quality

CHARACTERISTICS	CONTENTS
IMPURITIES%	9
MOULDY CUPS%	25
BLACK CUPS%	2
WRINKLED CUPS%	2
MOISTURE CONTENT%	7
PEROXIDE VALUE	1
FFA	0.8
SPECIFIC GRAVITY	0.93
IODINE VALUE	8.7

Table .6 Solar Tunnel Dried Copra Quality

CHARACTERISTICS	CONTENTS
IMPURITIES%	6
MOULDY CUPS%	11
BLACK CUPS%	3
WRINKLED CUPS%	2
MOISTURE CONTENT%	6.4
PEROXIDE VALUE	0.5
FFA	2
SPECIFIC GRAVITY	0.9
IODINE VALUE	8

5. Conclusions

From the test carried out for copra, the following conclusions were made. The solar dryer can raise the ambient air temperature to a considerable high value for increasing the drying rate of agricultural crops. The reduction in drying time occurs by increasing air flow rate. The food items are also well protected in the solar dryer than in the open sun, thus minimizing the case of pest and insect attack and also contamination. Although the dryer was used to dry copra, grapes, onion but it can be used to dry other crops etc. The drying time of copra reduced compared with natural drying method.

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