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Performance Evaluation of Farm Solar Dryer for Drying Agricultural Produce

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PAU model farm solar dryer was built and tested for spinach drying at college of technology and engineering, Udaipur. It is discovered that the temperature in the farm solar drier was 41.5 percent higher than the ambient temperature. The farm solar drier needs a total drying duration of 8hours for drying to lower the moisture content.

Introduction

Drying is one of the most practical means of preserving food and the quality of horticultural produce, and it is one of the most important unit operations conducted to increase the shelf life of agricultural / horticultural produce. Because of the high relative humidity, germs will proliferate if the drying process is not completed quickly enough. This frequently results in a significant drop in product quality.

Traditionally, food is dried by laying it out in a thin layer in the open sun. Although this approach is inexpensive and straightforward, it has drawbacks such as lack of control over the rate of drying, non-uniform drying, and the possibility of product deterioration owing to exposure to rain, dust, storms, birds, rodents, insects, and pests.

Materials and Methods

Moisture Content

It is defined as the ratio of the difference between the initial weight and final weight of the product to the initial weight of the product. This value will be calculated at every one-hour time interval during the experiment.

$$\%, Moisture\ Content = \frac{W_1 - W_2}{W_1} \times 100$$

Where,

W_1 = Weight of sample before drying, kg

W_2 = Weight of sample after drying, kg

Drying rate

Drying rate during experiment was estimated using the following equation

$$R = \frac{\text{The initial mass of sample} - \text{final mass of sample}}{\text{Time interval(min)} \times \text{drymatter(kg)}}$$

Where,

R = drying rate

Total heat requirement for drying

Total heat required for drying of the product is the function of amount of moisture present in the product and level up to which moisture of the product is to be brought down. It was estimated by using following equation (Rathore, 2009).

$$Q = M C_p (T_d - T_a) + M_w \lambda$$

Where,

Q = Total quantity of heat required for drying, kJ

M = Mass of the wet product, kg

Cp = Specific heat of wet product, kJ/kg K

Td = Drying air temperature, K

Ta = Ambient air temperature, K

Mw = Mass of water to be removed during drying, kg

λ = Latent heat of vaporization of water, kJ/kg

Drying efficiency

The drying rate is defined as the ratio of weight loss of material at a particular time interval and the difference in time period. Drying rate of sample will be determined by following formula,

$$\eta = \frac{m \times C_p \times (T_d - T_a) + M_w \lambda}{I \times A} \times 100$$

Where,

M = Mass of the wet product, kg

C_p = Specific heat of wet product, kJ/kg K

λ = Latent heat of vaporization of water, kJ/kg

Δt = Time difference, hour

T_d = Drying air temperature, K

T_a = Ambient air temperature, K

Exergy analysis

From the thermodynamics point of view, exergy is defined as the maximum amount of work that can be produced by a system or a flow of matter or energy as it comes to equilibrium with a reference environment.

Exergy is a true measurement of the quality or grade of energy and it can be destroyed in the thermal system.

The second law states that part of the exergy entering a thermal system is destroyed within the system due to irreversibility.

The exergy can be determined by using following formula:

$$\text{Exergy} = C_p\left[(T - T_\infty) - T_\infty \ln\frac{T}{T_\infty}\right]$$

The equation of exergy inflow can be written for the farm solar dryer as

$$Ex_{shni} = Ex_{di} = C_p\left[(T_{di} - T_\infty) - T_\infty \ln\frac{T_{di}}{T_\infty}\right]$$

Where,

C_{pda} = average specific heat of drying air

T_∞ = surrounding or ambient temperature

T_{di}= dryer inlet temperature

The equation of exergy outflow can also be written as follows

$$Ex_{shno} = Ex_{dco} = C_p\left[(T_{shno} - T_\infty) - T_\infty \ln\frac{T_{shno}}{T_\infty}\right]$$

Exergy outlet for farm solar dryer

$$Ex_{dco} = C_{do}\left[(T_{do} - T_\infty) - T_\infty \ln\frac{T_{do}}{T_\infty}\right]$$

Where,

C_{pda} = average specific heat of drying air

T_∞ = surrounding or ambient temperature

T_{do}= dryer outlet temperature

Exergy= Exergy inflow − Energy outflow

$$\sum Ex_L = \sum Ex_i - \sum Ex_o$$

$$\text{Exergy efficiency} = \frac{\text{Exergy inflow} - \text{Exergy outflow}}{\text{Exergy inflow}}$$

$$\eta_{Ex} = 1 - \frac{E_{xl}}{E_{xi}}$$

Results and Discussion

Performance of the system

No load testing

No load test was conducted to find out temperature variation profile at different locations in farm solar dryer. It was observed that the maximum temperature obtained inside the dryer was 59^{o}C at 12:00 h, while minimum was 31^{o}C at 9:00 h in the month of March.

The maximum ambient temperature was 34^{o}C at 12:00 h while minimum ambient temperature was 27^{o}C at 9:00 h. It was observed that there is an increment of 28^{o}C temperature inside the solar farm dryer as compared to ambient temperature. It was also observed that the maximum and minimum ambient solar radiation in this month was 910 W/ m^2 at 12:00 h and 650 W/m^2 at 9:00 h respectively. The trend of result for temperature and solar radiations during no load was plotted on graph as shown in Fig. 4.1. The variation of temperature and solar radiation was given in Appendix ‘B’.

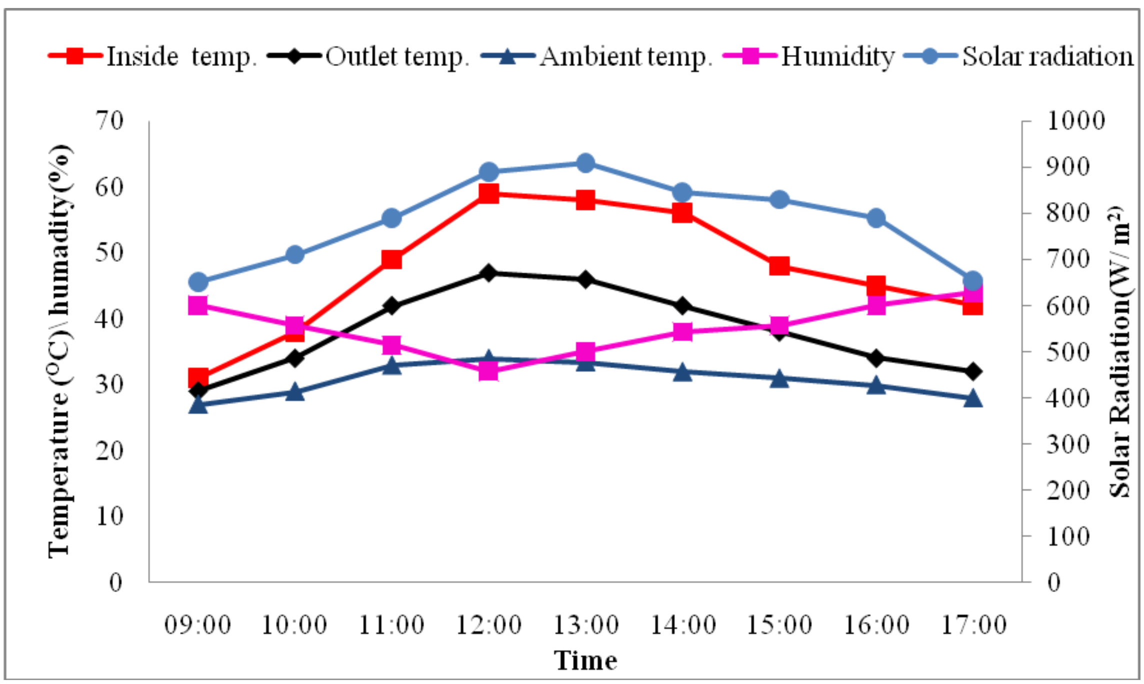
Full load testing

Full load test was conducted with a view to find out temperature variation profile at different locations in farm solar dryer. It was observed that the maximum temperature obtained inside the dryer was 53^{o}C at 12:00 h, while minimum was 29^{o}C at 9:00 h in month of March. The maximum ambient temperature was 35^{o}C at 12:00 h while minimum ambient temperature was 27^{o}C at 9:00 h. It was observed that there is an increment of 24^{o}C temperature inside the farm solar dryer as compared to ambient temperature.

Appendix.1 Data of dryer and ambient temperature under no load condition

Time (hr.)	Solar insolation (W/m2)	Relative humidity (%)	Ambient temperature	Inside dryer temperature	Exit air temperature
9:00	650	42	27	29	29
10:00	710	39	29	34	34
11:00	790	36	33	46	42
12:00	890	32	34	59	60
13:00	910	35	33.5	58	47
14:00	846	38	32	55	42
15:00	830	39	31	51	38
16:00	790	42	30	48	34
17:00	653	44	28	42	32

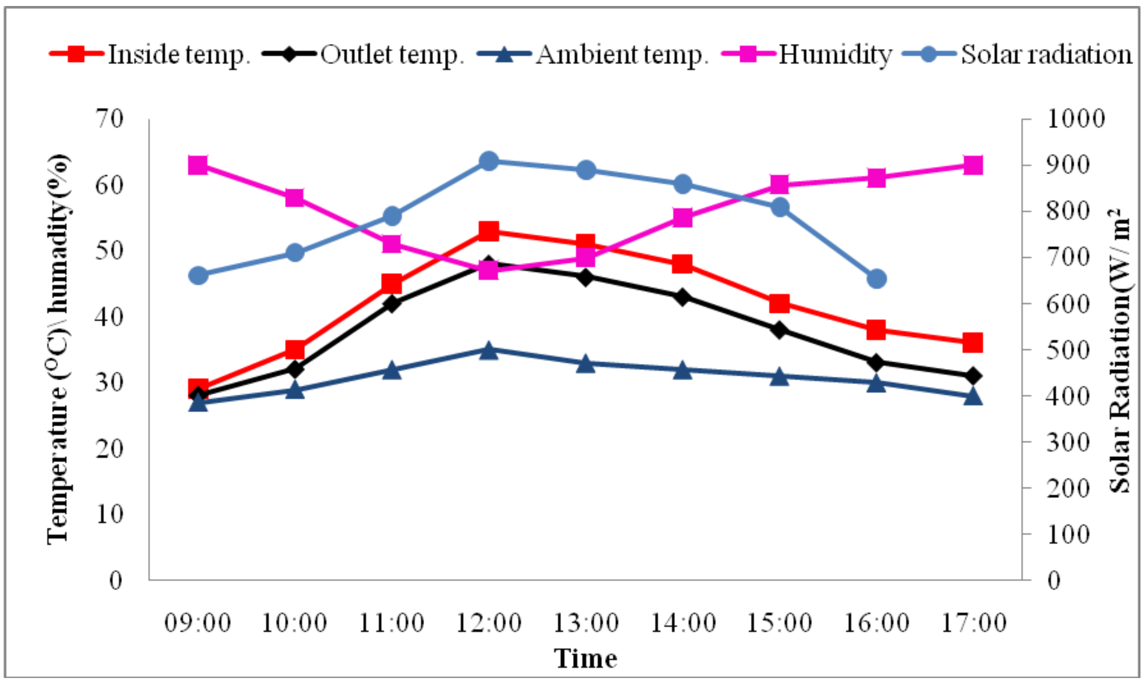
Fig.1 No load performance curve of farm solar dryer



Appendix.2 Data of dryer and ambient temperature under full load condition

Time (hr.)	Solar insolation (W/m2)	Relative humidity (%)	Ambient temperature	Inside temperature	Exit air temperature
9:00	660	63	27	29	28
10:00	710	58	29	35	32
11:00	790	51	32	45	42
12:00	910	47	35	52	48
13:00	890	49	33	49	46
14:00	860	55	32	46	43
15:00	810	60	31	44	38
16:00	770	61	30	43	33
17:00	710	63	28	38	31

Fig.2 Full load performance curve of farm solar dryer



It was also observed that the maximum and minimum ambient solar radiation in this month was 910 W/ m^2 at 12:00 h and 660 W/m^2 at 9:00 h respectively. The trend of result for temperature and solar radiation during full load was plotted on graph as shown in Fig. 4.2. The variation of temperature and solar radiation was given in Appendix 'C'.

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