Investigation of Thermal Performance and Characteristics of Solar Food Dryer Provided with Forced Circulation and variable Angle Booster Mirror

Sanjeet Kumar Manjhi[1] Prof. Manoj Kumar Singh[2]
[1]M. Tech. Research Scholar [2]Associate Professor
[1,2]Department of Mechanical Engineering
[1,2]B.I.T. Sindri, Dhanbad India

Abstract— Project Report Submitted to the department of Mechanical Engineering The solar drying process utilizes solar energy to heat up air and to dry food produce loaded, which is advantage in reducing wastage of agricultural produce and helps in preservation of agricultural produce. Based on the limitations of the natural sun drying e.g. exposure to direct sunlight, liability to pests and rodents lack of proper monitoring, and the highly cost of the mechanical dryer, a solar is therefore developed to overcome for this limitation. My project clearly reveals the performance of a solar dryer for food preservation. In this dryer, the heated air from a separate solar collector was passed through a grain bed. The results obtained during the test period revealed that the temperatures inside the dryer and solar collector were much higher than the atmospheric temperature during most hours of the day-light. The dryer possess maximum ability to dry food produce reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried produce.

Key words: Food Produce, Sunlight, Preservation, Solar Collector, Dryer

I. Introduction

The conventional drying system to preserve fruits, vegetables, grains, fish, meat, wood and any other agricultural produce is sun drying which is a free and renewable source of energy. In large-scale production, there are various known disadvantages of sun drying as damage to the food produce by animals, birds and rodents, degradation in quality due to direct exposure to sun drying, dew or rain, contamination by dirt, dust or debris. Also this system required more Labour and time, as crops have to be covered at night and during rainy weather, and have to be protected from attack by domestic animals. There is also a chance of insect infestation and growth of microorganism due to non-uniform drying. The advancement of sun drying is solar drying systems in which produce are dried in a closed system in which inside temperature was higher. More advantage includes protection against flies, pests, rain or dust. Several significant attempts had been made in recent years to harness solar energy for drying mainly to preserve agricultural produce and get the advantage from the energy provided by the sun. Sun drying of food produce is the most common method of food preservation in most part of India and the world because of solar irradiance being very high for the most of throughout the year. As this technique needs no energy during day time, it is more advantage to the small scale farmers who can't afford the electricity or other fuel for drying. Traditional open sun drying i.e. which comes directly from sunlight is a common and widely used method for drying of agricultural produce including fruits, vegetables and cash crops. It is the simplest way of drying foods by direct exposure of the produce to the sun. Even though solar drying is the cheapest method, the quality of the dried produce is very below standards. This method has some disadvantages including contamination, damage by birds or insects and slow or intermittent drying. Dried produce quality improvement and reduction of losses can be achieved by the introduction of suitable drying technologies such as solar drying.

However, most solar dryers that are constructed use only solar energy as a heat source for drying. This causes limits on the solar dryer because in night and clouding condition, there is not sufficient sunlight which provides heat. As a result, agricultural produce that are harvested in the rainy season are still subjected to spoilage. The solar dryer basically can be categories in two types such as free convection and forced convection solar dryer. In the free or natural convection solar dryers, the airflow is established by buoyancy induced airflow while in forced convection solar dryers the airflow is provided by using fan operated either by electricity/solar module or fossil fuel.

II. Research Objectives

The main objective of the research was to investigate the performance of a solar dryer in addition to a blower which can be used as an additional forced circulation and enhancement dryer performance with the help of booster mirror.

A. *Specific Objectives*

The specific objectives of the research were:

1) To perform a solar dryer with the help of solar collector and enhance the efficiency by using s booster mirror and blower.
2) To investigate the performance of the dryer using different parameters such temperature, moisture content of the produce, drying period, drying rate and efficiency.
3) To compare the performance of the solar dryer with and without booster mirror.

III. Indirect Solar Dryers

In indirect solar dryers, a solar collector is used to heat the air entering the drying cabinet where the crops are placed. The heated air is made to pass through the drying bed for moisture removal by convective heat transfer between the wet crop and the hot air. The solar collector has an area of 0.864 m2 and the air duct has a gap of 0.2 m. drying test of food produce taken wheat, cabbage chilli and cauliflower showed that the mass of wheat is reduced to 923gm from 1100gm without booster mirror and reduced to 896gm with the help of booster mirror. Drying period taken for four hours. And cabbage taken 1000gm which reduced upto 200gm without booster mirror and it reduced to 180gm with the help of booster mirror during four hours drying period. When using the solar drier at the test location, the temperature in the collector and the drying chamber reached approximately 80°C and 50°C respectively. The moisture content was reduced from 80% on wet basis during test period of 4 sunshine hours. It was also shown that the drying rate was faster on the lower shelf that is closer to the collector than the upper shelf.

It was indicated that, due to high humidity in India, some of the tools used to construct the dryer started to corrode after only a short period of time which affected the modification of dryer. The large size of the dryer had also made it difficult for handling while moving it from one place to another. Stated that it is unreliable to use the sun as the only source of energy. Due to cloudy or rainy weather, tests that were supposed to be done were not completed. Even though drying in India is possible during the dry season, it is difficult to preserve food grains during the rainy season. A future work was also recommended on studying the weight gain during the night time because of the high humidity. An indirect mode active solar dryer with easily available local materials such as wood, glass sheet, metal sheet, chicken net and mosquito net. They carried out tests under with and without booster mirror conditions. During without booster mirror test the maximum temperature in the indirect solar dryer reached up to 44°C while the ambient temperature was 42°C. For the boosting condition, 1000 g of cabbage with 81.7 % of initial moisture content on a wet basis was considered. It took 4 hours to reduce the moisture content of the cabbage. The drying rate of the produce in the indirect active solar dryer was 204.25 g/h with booster mirror while it was 200g/h without booster mirror drying

IV. Drying Efficiency

Drying efficiency is the ratio of the energy needed to evaporate moisture from the produce to the heat supplied to the dryer. This term is used to measure the overall effectiveness of a drying system. But it is not best suited for analysing one dryer with another due to different factors such as the particular material being dried; the air temperature and mode of air flow may differ for various dryers.

$$\text{Dryer efficiency } \eta_d = \frac{\dot{m}_m * h_{fg}}{\dot{m}_a * C_{pa}(t_{a4} - t_i)} * 100$$

M_m – weight of moisture evaporated, kg

L – Latent heat of evaporation of water (at temperature of dryer), kJ/kg

t – drying time

V. Drying Rate

Drying rate is the amount of evaporated moisture over time.

$$(M_i - M_f)/t$$

M_i = Initial mass of produce

M_f= Final mass of produce

t = drying period

VI. Drying Temperature

Drying temperatures which is used in solar dryer such as fruits and vegetables to be between 37.7-54.4°C Higher temperature may cause sugar caramelization (browning of sugar) of many fruit produce and food produce loses their vitamins and colors when drying. Hence, for designing the dryer, average drying temperature, T_d, of 45°C was considered.

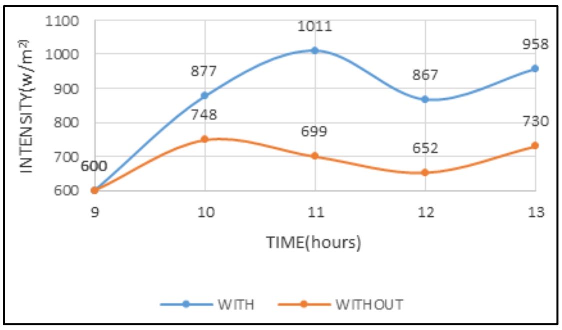

Fig. 1: Effect of boosting on intensity with time

VII. Comparison between with and without Booster Mirror of Air Inlet Temperature, Collector Plate Surface Temperature and Final Mass of Produce.

Sl. No		With Booster	Without Booster
1	T_a	52.1	44.9
2	T_s	61.55	59.05
3	M_f	183	200

Table 1: Experiment done at water head 0.06m and initially cabbage taken 1000gm with booster mirror

A. *Plate Surface Temperature*

Sl. No.	Time (Hour)	T_{sb1}	T_{sb2}	T_{sb3}	T_{sb4}	T_o	RH_o
1	9:00 AM	68	75	78	79	35.8	45%
2	10:00AM	54	68	56	68	42.3	41%
3	11:00 AM	55	63	58	64	39.8	37%
4	12:00 AM	59	61	54	62	40.5	35%
5	01:00 PM	46	56	50	57	41.6	32%

Table 2: Plate Surface Temperature

B. *Air Inlet Temperature*

Sl. No.	Time (Hour)	T_{ab1}	T_{ab2}	T_{ab3}	T_{ab4}
1	9:00 AM	60	61	61	62
2	10:00 AM	47	48	49	49
3	11:00 AM	50	52	53	53
4	12:00 AM	52	53	53	54
5	01:00 PM	46	47	47	48

Table 3: Air Inlet Temperature

C. *Grain Dryer Sensor Temperature*

Sl. No	time	T_{gb1}	T_{gb2}	T_{gb3}	T_{gb4}	T_{gb5}	T_{gb6}
1	9:00	49.5	55	48.4	56.6	40.9	44.5
2	10:00	50.6	46.4	43.4	46.1	49.2	46.4
3	11:00	49	43.8	45.2	48.1	50	45.3
4	12:00	48.3	42	46.5	49.8	52.2	44.4
5	13:00	47.5	42.3	47	51.2	51.8	44

Table 4: Grain Dryer Sensor Temperature

D. *Balance Reading*

Sl. No.	Time (Hour)	Cabinet Drying Mass
1	9:00 AM	1000 gm
2	10:00 AM	495 gm
3	11:00 AM	282 gm
4	12:00 AM	225 gm
5	01:00 PM	183 gm

Table 5: Balance Reading

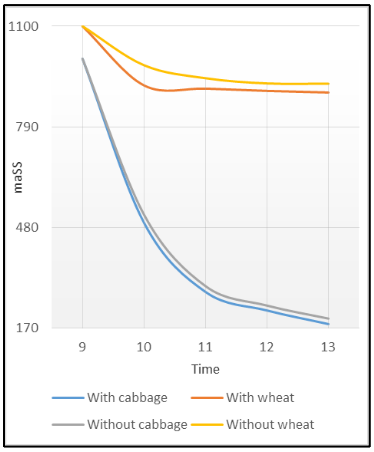

Fig. 2: Variation of loss of moisture for different produce (with and without booster mirror) with time

VIII. CONCLUSION

The comparison of performance of an indirect type solar dryer with and without booster mirror. The dryer is robust in structure and hence hard to operate and handle. An additional system, two booster mirrors are used to enhance the temperature by directly focused on the solar collector plate was included in order to make drying continuous throughout efficiently.

Under no-load condition, without booster mirror, the average collector temperature reached 65^{oC} and that of the dryer reached 42.4°C while the average ambient temperature was 35°C. When the load condition the average collector temperature reached 53.87°C and that of the dryer temperature reached 40.57°C and average ambient temperature. 41.37°C.

With booster mirror no load average collector temperature 73.25°C ambient temperature 35°C and dryer reached 47.08°C. With load average collector temperature 55.56°C average ambient temperature 41.75°C and dryer reached 45.72°C.

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