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Experimental analysis of solar drying system for vegetable and fruits

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***Abstract*— A performance analysis of a sun drying system for vegetables and fruits is the subject of this study (Grapes, Potato, Onion and Banana). Drying 5 kg of Vegetable & Fruits using the dryer Study the influence of drying, as well as environmental and operational conditions, on the performance of the drier. The experiment was conducted both with and without a reflecting mirror, and the results were compared. In the absence and presence of reflecting mirrors, the highest collector outlet temperature was 66 ^{o}C and 81 ^{0}C, respectively. According to the results, ginger can tolerate a maximum of 65 ^{0}C in a dryer without a reflecting mirror, but not one with one. The maximum temperature for ginger is 65 ^{0}C when the dryer has a reflective mirror installed. On average, efficiency without and with a mirror was 53.14% and 79.39% whereas it was 53.14% when using a mirror and 61.84% when using a mirror, respectively Reflectors enhance the average efficiency of the collector by 8.04%, according to the study. Ginger's original moisture content was 82.95%, and it required 16 hours of daytime drying in a solar dryer to achieve its equilibrium moisture level of 12%, and 48 hours of open sun drying with 8 hours of drying each day to reach the same level. Fruits and vegetables dried in a dryer took 66.7% less time and had better quality than those that were sun-dried.**

Keywords— Solar Dryer; Forced Convection; Solar Radiation

I. Introduction

People in India rely heavily on agriculture as a means of subsistence. Due to limited storage and marketing facilities, fruits, vegetables, spices, and whole grains are produced in high numbers in this area, but the money derived from these goods is typically minimal. Farmers are increasingly using drying to sell fresh fruit as the demand for high-quality fruit continues to rise globally. [1].

Drying is an excellent way to conserve food and dry out the sun food is the ultimate food technology suitable for sustainable development. Drying was probably the first method of food preservation used is human, even before cooking. Produced agricultural products are dehumidified so that they may be securely kept for a lengthy period of time. Man's earliest technique of drying a farm product, "sun drying", includes laying agricultural items in the sun on carpet, ceiling or floor and letting them dry. Unjust because a farm product is left in the open sky where it is susceptible to harm from severe weather conditions such as rain or wind or damp and dust. Unjust because birds, insects and rodents (insects) might cause loss of production, it depends entirely on good weather and moves very slowly the rate of drying at the risk of mold growth has thus resulted in deterioration and decay of the product. This process also requires a large area of land, time-consuming and highly efficient very much. [2]

Manufacturing artificial equipment began with the growth of culture and industry, but this process is more powerful and expensive, ultimately raising the cost of

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manufacturing. "Solar eclipse" is a result of recent attempts to enhance solar drying.

In the sun's heat, solar dryers are special devices that control the drying process and protect the agricultural product from damage by insects, dust, and rain. Compared to the "sun dry" environment, solar dryers produce higher temperatures, lower humidity, and lower product moisture content and reduce spoilage during the drying process. In addition, it takes less space, takes less time and is cheaper compared to the artificial machine. Therefore, solar drying is the best way to solve all the problems of drying and mechanical drying [4]. The solar dryer can be seen as one of the solutions to the world's food and energy problems. By default, most agricultural products can be stored and this can best be achieved with the use of solar dryers.

Solar dryers are a very useful tool for:

1. Drying of agricultural crops.
2. Food and vegetable processing industries.
3. Drying of fish and meat.
4. Dairy industries for powdered milk production.
5. Time for wood and wood.
6. Fabric textile industry, etc.

Therefore, a solar dryer is one of the many ways to use solar energy efficiently to meet man's need for energy and food supply.

II. Material and methods

In figure 1, the frame of solar panel is shown. We made 1.524 × 0.762 m^2 (5ft × 2.5ft) and 16mm thick wooden frame. Two wooden plates having 10 holes of 6cm diameter are set at 15cm distance separated from the both end of frame. Rock wool is set at base and at side part of an edge to forestall the heat losses.

Drying chamber is box type design and hot air from the solar collector compartment is passed through this box. We used plywood for making this chamber because it is not so expensive. The size of box is 0.6096m × 0.4572m (2ft × 1.5ft) and the depth is 0.4572m. Number of trays is set in that container which is utilized for setting food on it. The box is separated in their part as appeared in fig.1. In that chamber 3 trays are given which are comprised of metal and wood. These trays are arranged in appropriate manner with the goal that it can put inside it or eliminate from it. It is design in such a manner so potato, onion, carrot, apple cut can spread appropriately.

Absorber plate or pipe present in the solar heater assembly is get warmed because of solar radiation falling on it. An air from climate will go into the solar heater assembly gathering where the absorbed plate is put. As the air present over there is get warmed because of convection. This heated air will push ahead as its density will drop and it goes into drying box where the damp food is set. This kind of dissemination of heated air is called thermo siphon activity. While heated air moving through the garbage will eliminate the moisture from it. Arrangement of electrical heating coil will come into picture when drying is needed to convey during evenings and overcast days.

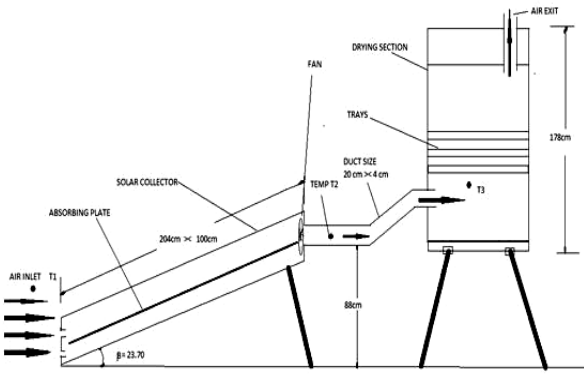

Figure 1. Basic Schematic details of experimental set up

Copper constantan thermocouples are used to measure the temperature at various locations of the system. A solar power meter of range 1999 W/m^2 is used to measure the solar radiation incident on the surfaces. A thermo hygrometer is used to measure the ambient air temperature and relative humidity of the air. The velocity of air is measured using vane type anemometer. An electronic balance of 0.001 g accuracy is used to measure the weight of the drying product. The moisture measurement is done in moisture analyzer by taking 5gms of drying products.

III. Performances analyses

The weight change over time to calculate the moisture change over time A drying rate constant ‘k’ was derived by fitting moisture content and time to a thin layer drying equation of the form moisture ratio (MR)

$$MR = \frac{M_t - M_e}{M_o - M_e} = e^{-kt} \quad (1)$$

Where M_t, M_o, M_e is the moisture content in the product in % at any time t, at initial and at equilibrium respectively and k is the drying constant t is the drying time.

When it comes to estimating the effectiveness of a solar drying system, drying rate and dryer thermal efficiency are the most important variables [12]. A material's moisture content and equilibrium moisture content should be taken into account while determining drying rate [13]. Mathematically, it can be expressed as thin layer equation drying rate,

$$\frac{dm}{dt} = -k(M_t - M_e) \quad (2)$$

The instantaneous thermal efficiency of the solar air heater was estimated by using equation (3) according to (Kadam and Samuel) [14]

Instantaneous efficiency,

$$\eta = \frac{mc_p(t_o - t_a)}{AI} \times 100 \quad (3)$$

Where, m = mass flow rate Kg/s, Cp = specific heat of air KJ/Kg-k, To = outlet collector temperature, Ta = ambient air temperature, A = area of collector m^2, I = solar intensity W/m^2

Due to weight loss, several structural changes occur during drying. The mass shrinkage ratio is the most significant structural variation that appears on crops [15].

$$\text{Shrinkage ratio, } SR = \frac{W_t}{W_i} \quad (4)$$

Where, W_t is the weight of product at time t and Wi is the initial weight of product.

IV. Results and Discussion

Figures 2 and 3 shows the hourly variation of the measured solar radiation and relative humidity during the typical experimental run, which are employed for calculations As the time of day goes first it is seen that the intensity of solar radiation goes on increasing and it reaches to its maximum value of 1054 w/m^2 at 12 pm. Then it starts decreasing as the time passes. The relative humidity which is measured to know the moisture absorbing capacity of the air. As the lower percentage of the relative humidity shows the higher capacity of the moisture absorption of air. The relative humidity goes on decreasing as solar radiation increases and reaches to its minimum value of 22% at 2 pm and then it starts increasing and it at its maximum value of 33% at 6 pm.

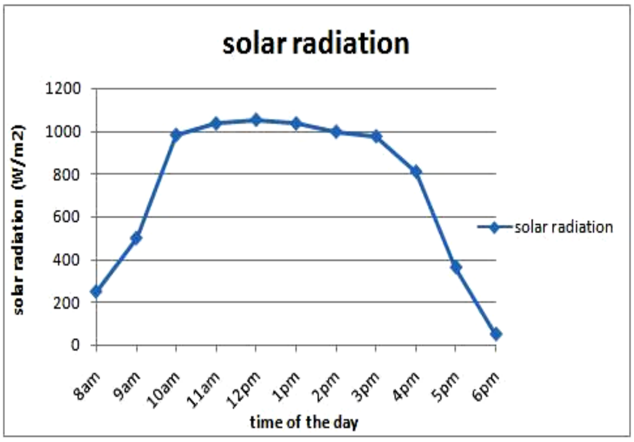

Fig.2. Hourly variation of solar radiation

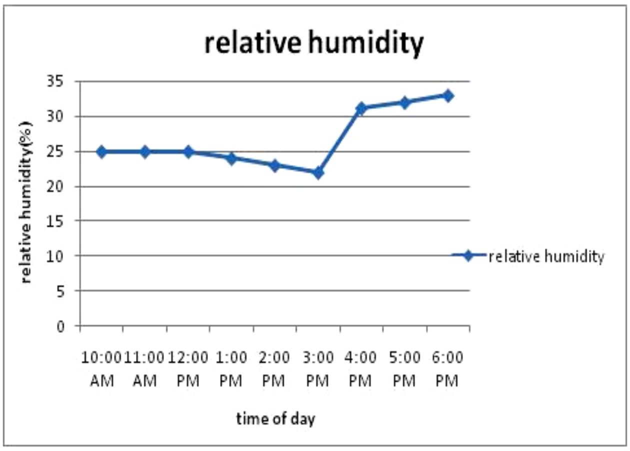

Fig. 3 Hourly variation of ambient relative humidity

Figures 4 and 5 shows the variation of the Ambient air temperature (T_a), collector outlet temperature (T_o), and temperature inside dryer (T_d) without and with reflective mirror respectively. It can be seen that the collector outlet temperature increases to a maximum of 66^0C and 81^0C at 12.00 PM without and with reflective mirror respectively and starts decreasing as the solar radiation decreases. It can be seen that the average temperature inside the dryer with reflective mirror above 65^{0}C which is higher than the maximum allowable temperature for ginger though the efficiency of dryer increases. Hence the drying characteristic of ginger without reflective mirror studied further.

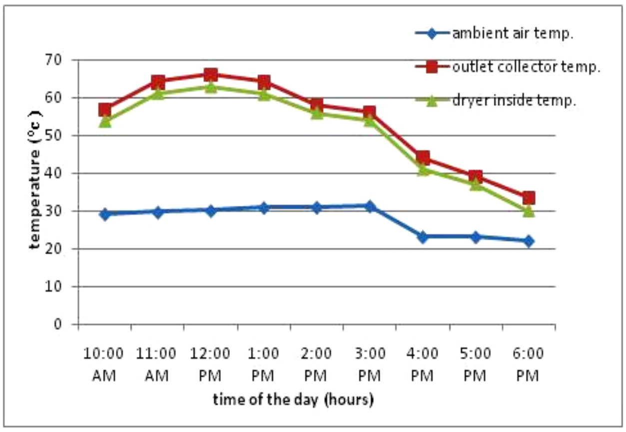

Fig. 4 Hourly variation, ambient temperature, collector outlet temperature and the temperature inside dryer without reflective mirror

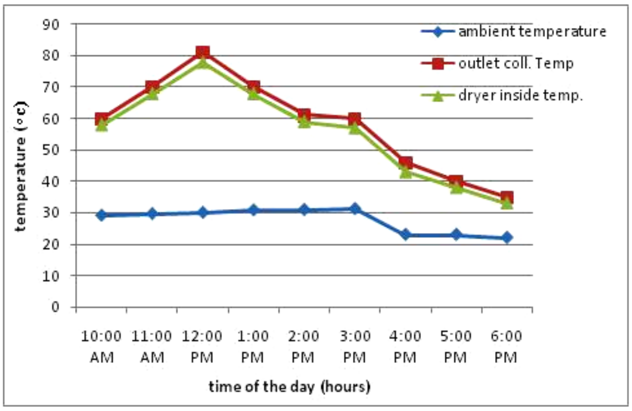

Fig. 5 Hourly variation, ambient temperature collector outlet temperature and the temperature inside dryer with reflective mirror

The weight loss and the moisture content variation of the ginger with drying time are shown in Figs. 6 and 7, respectively. A weight loss of about 80% is achieved through solar energy. The graphs show that as drying time rises, the rate of moisture loss reduces until the ginger reaches equilibrium moisture content (MR=0). According to this process, drying happens mostly during the rate-falling phase. It required 48 hours of drying in the open sun with 8 hours of drying each day to reduce the moisture content of ginger from 80.95 percent to 12 percent. When using a dryer, 66.7% less time was required to dry clothes. Because of the free moisture content on the product's surface, weight loss is initially more rapid.

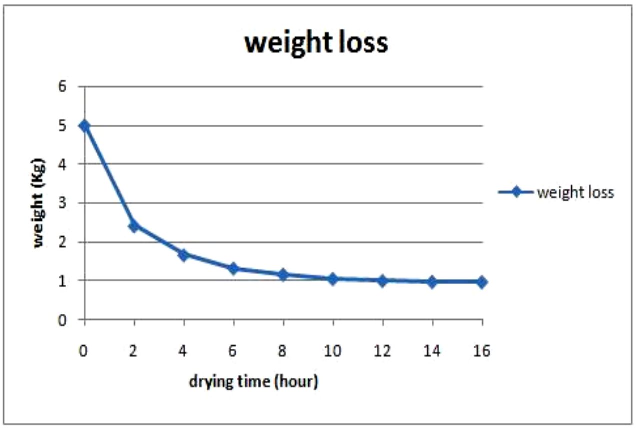

Fig.6 The weight loss of product during solar drying

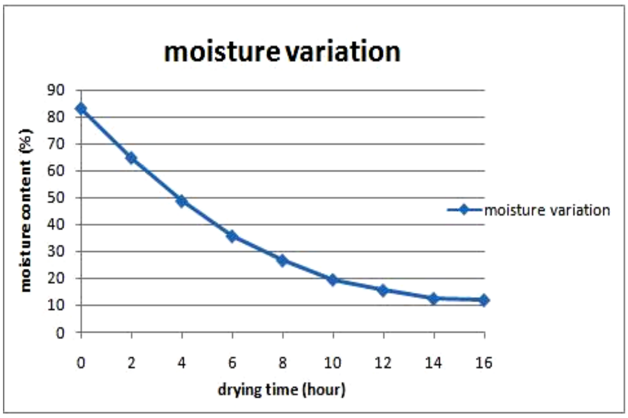

Fig.7 The variation of moisture changes with drying time

Fig. 8 shows the influence of drying time on moisture ratio. The moisture ratio decreases significantly with decreased drying time. Fig. 9 presents the variation of mass shrinkage ratios with the drying time and is calculated using equation Wt/Wi given by Midilli [15]. To determine the mass changes during drying, it is significant to determine the mass shrinkage of the drying products.

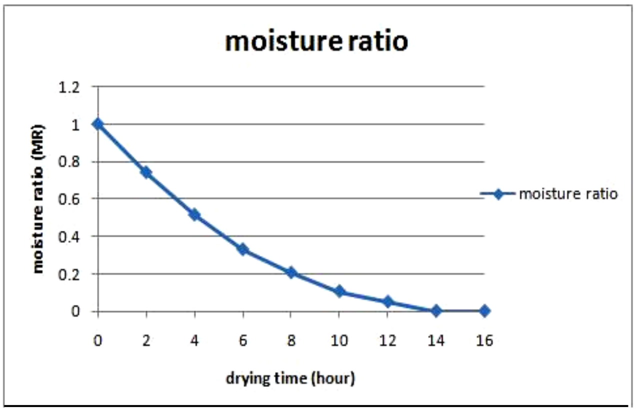

Fig.8 The variation of the moisture ratio with drying time

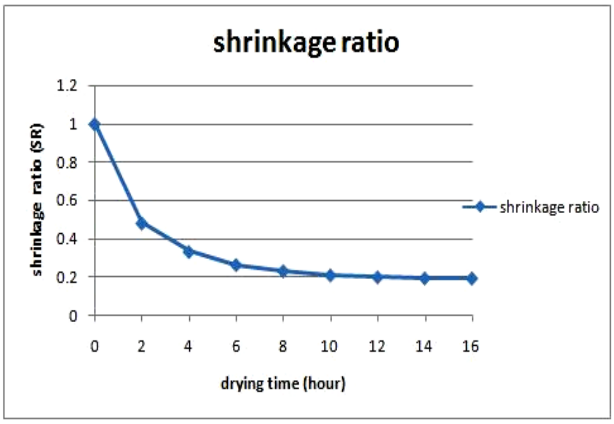

Fig 9 The variation of the shrinkage ratio with drying time

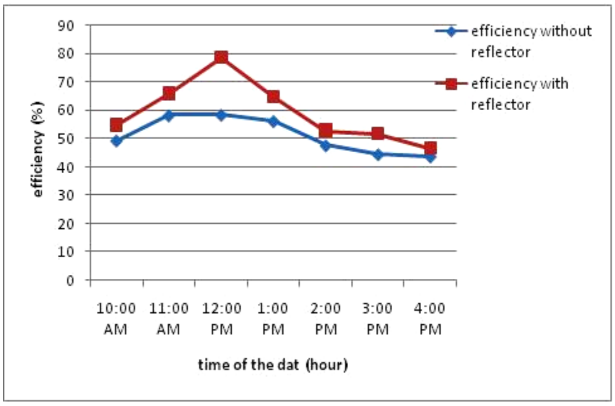

Fig. 11 variation in efficiency with time

The drying rate curve is shown in Fig. 10. The results show that dryness occurs during the fall with a strong drop in moisture content at the beginning and slows down in the next half. This is because in the next phase, the suspension occurs with the spread of moisture within the product and, the reduction of the product can provide resistance to moisture movements. The best quality of the product is obtained by slightly drying because the temperature is a major factor in determining the quality of the dried product. Measurement time is not always observed during drying probably due to the thin layer of product that does not provide continuous moisture removal.

Figure 11 shows the variation in efficiency of collector with time .it is seen that the efficiency of collector goes decreasing as time of the day passes this is because of the decreasing solar radiation. Maximum instantaneous efficiency was found to be 59.4% and 79.39% and average was 53.14% and 60.18% without mirror and with mirror respectively. It is seen that the average efficiency of the collector is increases by 8.04% with reflector.

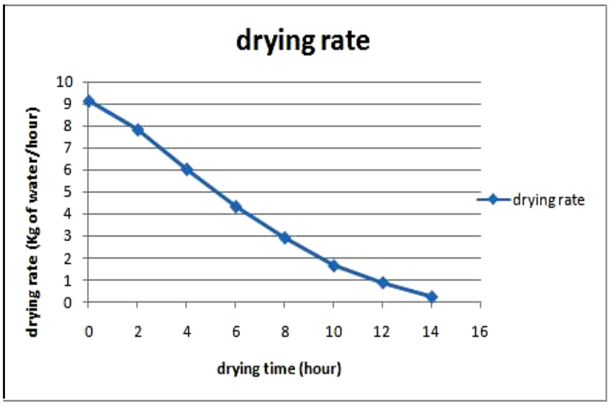

Fig.10 The variation of drying rate as a function of drying time

V. Conclusions

The collector outlet max temperature was 66^{0}C and 81 ^{0}C without and with reflective mirror respectively. It was found that the average temperature inside the dryer without mirror was 63 ^{0}C which is below the maximum allowable temperature for ginger of 65 ^{0}C and with reflective mirror was above 65 ^{0}C which is higher than the maximum allowable temperature for ginger. Maximum instantaneous efficiency was found to be 59.4% and 79.39% and average was 53.14% and 60.18% without mirror and with mirror respectively. It is seen that the average efficiency of the collector is increased by 8.04% with reflector. The initial moisture content of Vegetable & Fruits was 82.95% and it took 16 hours of day time to reach its equilibrium moisture of 12% when dried in solar dryer and took 48 hours in open sun drying with 8 hours of drying per day. The time of drying reduced.

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