Experimental Investigation of Single Layer Drying Behavior of Potato in a Fabricated Tunnel Drier

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Abstract—Experiments are conducted in a tunnel dryer using cubic shaped (10x10x10mm) potato for various drying air temperature (40.1-53.3^{O}C), velocity (1.1, 1.4, 1.9 and 2.3 m/s) and relative humidity (16-40.5%) values. The temperature and relative humidity are measured and recorded every 20 min. at fan inlet, upstream and downstream of the tray, the velocity is measured only at the tunnel exit. The measured data is used to obtain drying and drying rate curves. The curves indicate that drying process takes place in the falling rate period except very short unsteady-state initial and constant rate periods.

Index Terms— *Keywords:- Hot Air Drying, Tunnel Drying, Air Flow Rate, Drying*

1 Introduction

Drying of agricultural products is one of the most important aspects covered in the post-harvest technology in processing engineering. "The term drying refers to the removal of moisture from agricultural product to a level that is in equilibrium with normal atmospheric air in order to preserve the quality and nutritive value as food, feed and its viability as seeds." Drying involves a large amount of heat energy, which is either from renewable or non-renewable sources. The shortage of non-renewable sources has compelled the related authorities and scientist concerned to exploit the use of renewable sources of energy such as solar, biogas, wind etc.

The age old method of drying materials with solar energy by spreading on the ground for direct exposure to solar radiation requires open space, manual labor for material handling and involves low temperature heat for removal of moisture. To reduce any possible contamination and improve the product quality, it is essential that the drying be enclosed and dehydrated under controlled conditions, non-uniform drying may result in formation of cracks in the kernels.

In order to avoid the application of conventional forms of fuels and cut down the operative costs of drying of products alternative source of energy is to be allocated which is cheaply or freely available, solar energy can effectively be utilized for the purposes as it is abundantly available and may serve the task. Direct lined glass/plastic covered solar dryers often referred as natural dryer. Usually one or two layers of transparent covers are provided depending upon the temperature required for drying. In directly heated solar dryers in whom air was heated in a solar heater was supplied to separate drying chamber. Different investigators worked on different designs and configuration of air heaters.

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The present paper discusses the design and fabrication of tunnel drier to dry high moisture hygroscopic grain (Potato) in three consecutive trays in 6 hours a day for two continuous days. In present case the drier was fabricated at Allahabad in Uttar Pradesh (India). The overall performance has been encouraging and discussed in the paper.

2. MATERIALS AND METHODS

2.1 FABRCATIONAL ASSUMPTIONS

The following parameters were considered while fabricating the solar dryer.

I Scale of use.
II Temperature it retains in all-weather consideration.
III Type of material to be dried.
IV Efficiency of drying.
V Cost economics.

Based on the above parameters the following assumptions were made:

I the loss of heat from the cabinet was negligible.
II there is uniform circulation of air inside the dryer.
III there is no air leaks from the cabinet.
IV there is no loss of heat from the duct connecting collector and drier

2.2 FABRICATION OF DRYER

A tunnel dryer with a height of 250 mm, a width of 200 mm and a total length of 1602 mm is constructed to study the drying behavior of Potato cubes. The dryer is composed of two major parts; an air preparation unit and a drying tunnel. A picture and a schematic diagram of the dryer are given in Figure 1 and 2 respectively.

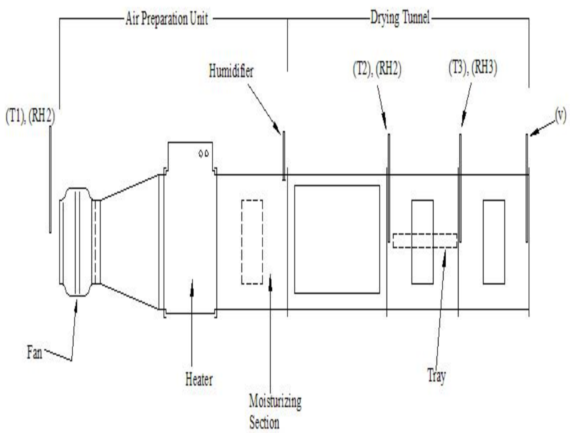
Air preparation unit consists of a fan, a heater and a humidifier. The air is sucked by the fan, passed through a filter to remove the contaminants prior to the heater. The fan has a 5-step velocity controller, whereas the heater has a 4-step temperature controller, each of which has a power of 6 kW. After passing through the heater, the air reaches the humidification section in which the moisture is added manually to reach the specified relative humidity. The humidified air is subsequently introduced to the drying tunnel.

The drying tunnel is a modular unit with a length of 850 mm. It is divided into two parts:

- First part is evacuation channel with a length of 350 mm. The dried yield is taken out using the lateral cover.
- The second part consists of two modules with the same length of 250 mm. Each module has 2 racks inside.

The drying unit is insulated to prevent heat loss to the surroundings by fiber glass panels covered with thin layer aluminum sheet.

The Potato are brought from the local market and stored in the refrigerator at 4^{O}C. They are divided into four parts, taken their cores out and then cut into 1000 mm^3 via mechanical cutter.



(a) Schematic of Drier

2.3 Experimental Procedure

The experiment was conducted at the Mechanical Engineering Department, Shepherd School of Engineering and Technology of Sam Higginbottom Institute of Agriculture, Technology & Sciences (Deemed-to-be-University), Naini, Allahabad.

2.3.1 Drying Experiment

Potato cubes are dried as single layer at various temperature, relative humidity and velocity values of drying air. Drying of potato cubes started with an initial moisture content of approximately 85% (w-b) and continued until no further changes in their mass were observed e.g. to the final moisture content of about 11% (w-b) .

The potato used in the experiments are kept two hours in room temperature for stabilization prior to the experiments. The stabilized potatos are peeled; the cores are taken out and then cut into 10^3 mm^3 cubes with a mechanical cutter. The tray is loaded as a single layer. Potato cubes are approximately 0.95 g each and approximately 200 pieces are placed on the tray.

(b) Photo of Drier

During the experiments; temperature, velocity and relative humidity of drying air is recorded every 20 minute. The temperature and relative humidity sensors are located at the inlet of the fan (T1, RH1), upstream (T2, RH2) and downstream of the tray (T3, RH3). The velocity sensor (v) is located at the exit of the tunnel.

The samples taken from five different locations of the tray are weighed at every 10 minutes. Drying is terminated when the moisture content dropped to 11% (w-b)

4. RESULTS and DISCUSSION

Experiments are conducted to determine the influence of temperature, velocity and the relative humidity of drying air on the kinetics of potato drying. Under various drying air conditions; moisture ratio and drying rate is determined depending on drying time.

4.1 Influence of Temperature

Three set of experiments are conducted to exhibit the temperature effect. The velocity and relative humidity values are kept constant and temperature is the only variable. Each group consists of three experiments. First of which is conducted without humidification while the second and third experiments are conducted with humidification. Initial moisture content of potato cubes for each group is determined as 6.19±1.04 g water/g dry matter.

As it can be noticed from collected data that the relative humidity at the dryer inlet (RH1) is not constant, because of the uncontrolled laboratory environment. Distributions of the relative humidity at the dryer inlet (RH1) and drying air (RH2) are plotted in Figure 4.1 As it can be seen from the Figure, relative humidity values at the dryer inlet change drastically during the experiment. While keeping the average relative humidity of drying air (RH2) around 20.5%, RH1 changes between 25-42.5%. Therefore, during the experiments, it is difficult to keep the relative humidity of drying air constant.

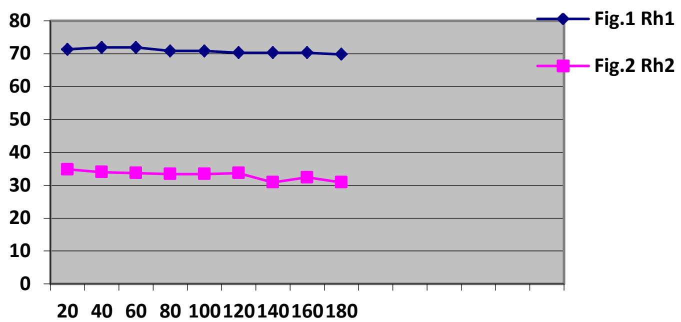


Fig.4.1 Relative humidity at drier inlet(RH1) and Drying Air (RH2) versus Drying Time

Distributions of the temperature at the dryer inlet (T1) and drying air (T2) are plotted in Figure 4.2 for Experiment 1.1. When temperature values are compared with relative humidity values, the change of temperature values at the dryer inlet and at the drying air is smaller.

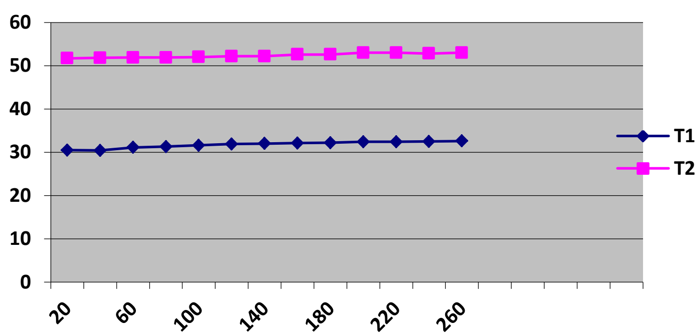


Figure 4.2. Temperature at Dryer Inlet (T1) and Drying Air (T2) versus Drying Time

For the Group No. 1, while the relative humidity and velocity of drying air is kept constant at 20.5% and 0.8 m/s, three experiments are conducted for the drying air temperatures of 40.1, 48.1 and 57.3°C, respectively. Drying time with respect to temperature is shown in Figure 4.3.

As it can be seen from the Figure 4.3, at constant relative humidity and velocity, increasing the temperature decreases the drying time as expected. Drying time is decreased about 21% with a temperature increase of 8°C from Experiment 1.1 to 1.2. But further increase in temperature at Experiment 1.3 which is 9.2°C, causes only 8.7% decrease in drying time. The relation between the temperature and drying time is not linear which proves the exponential characteristic of drying curves (Mujumdar 2006, Brennan 2006).

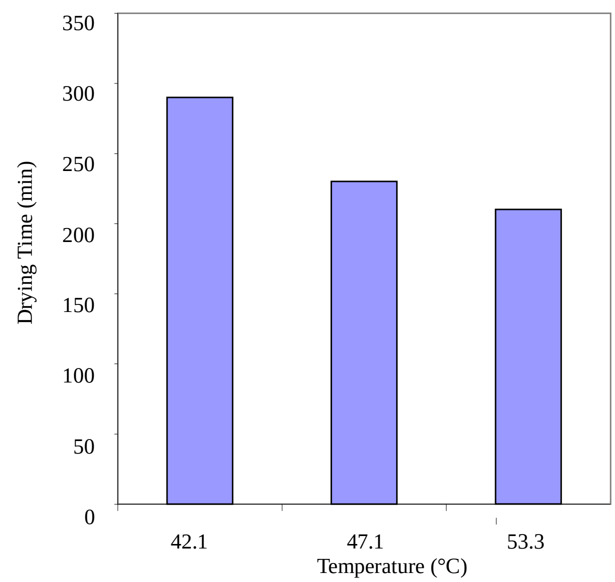


Figure 4.3. Drying Time versus Drying Air Temperature at 20.5% Drying Air Relative Humidity and 0.8 m/s Drying Air Velocity

The variation of the moisture content of the potato cubes with time is plotted in Figure 4.4. The results indicate that although at the first 20 minutes of the drying process decrease of moisture of the product is the same at each temperature, for the rest of the drying process decrease of moisture changes with temperature. Increasing drying air temperature increases moisture loss of the product non-linearly as shown in Figure 5.3. Initial moisture content of the potatos is determined as 85.8%. When it is reduced to 11%, the experiment is terminated. The collapse of the drying curves at the beginning of the process indicates that drying is controlled by external conditions. When the curves deviate from each other, drying is mainly controlled by internal mass transfer resistance. Fig 4.5 exhibits the distribution of drying rate with respect to moisture content. Drying rate is calculated using Equation 5.1. High drying rates at the first 10 minutes is related to the difference between temperature of potato cubes and drying air.

ISSN 2229-5518

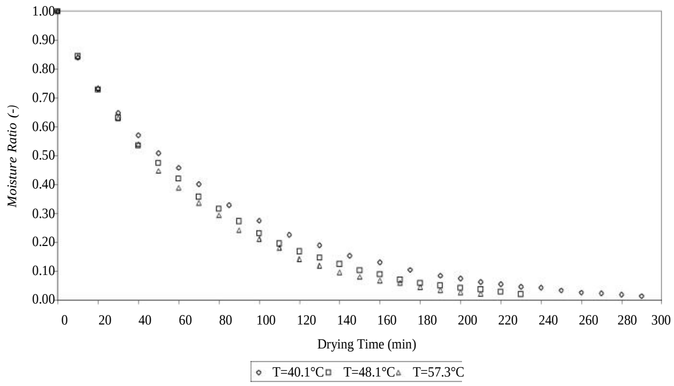


Figure 4.4. Moisture Ratio versus Drying Time at 20.5% Drying Air Relative Humidity and 0.8 m/s Drying Air Velocity for Various Drying Air Temperatures

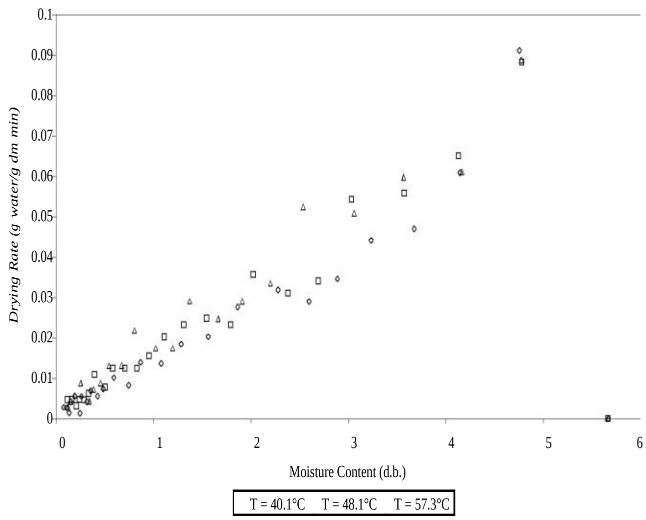
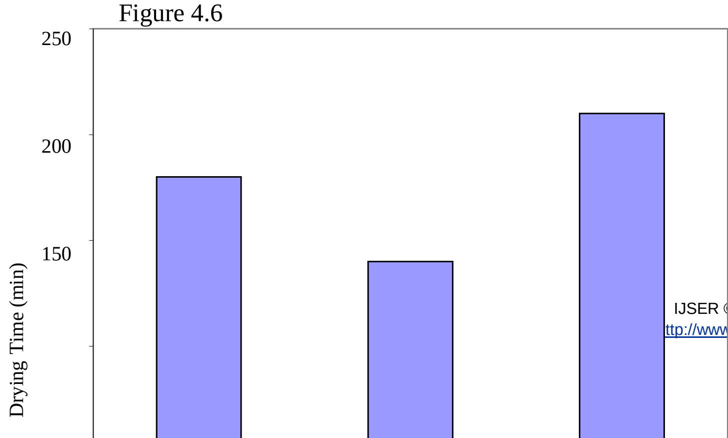


Figure 4.5. Drying Rate versus Moisture Content at 20.5% Drying Air Relative Humidity and 0.8 m/s Drying Air Velocity for Various Drying Air Temperatures

Drying process generally occurs in two different periods; namely constant rate period and falling rate period. It is seen from Figure 4.4 and 4.5 that constant drying rate period is very short and falling rate period can be divided into two parts. First falling rate period is continued till moisture content of potatos reach to approximately 33% (w-b) which is longer than second falling rate period.

Drying time change with relative humidity is shown in Figure 4.6



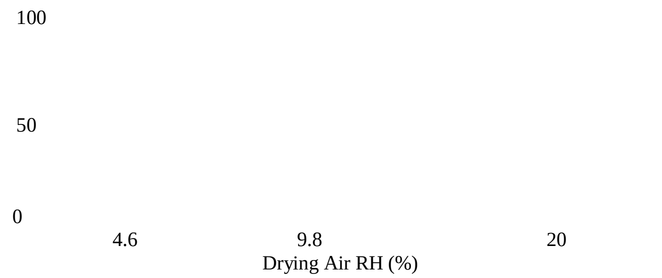


Figure 4.6 Drying Time versus Drying Air Relative Humidity at 59.8^{o}C Drying Air temperature and 0.8 m/s Drying Air Velocity

Figure 4.6 shows a decrease then an increase with increasing relative humidity which is different than previous experiments. This may be due to a competition in the rates of evaporation and skin layer formation in the product. The relative humidity range should be extended to have a better sight.

5. CONCLUSIONS

Two groups of Potato drying experiments are performed in a tunnel dryer to investigate the effects of temperature, velocity and relative humidity of air on the drying kinetics of potato. The first three groups are tested to investigate the effect of drying air temperature (32.1-42.3^{O}C), and the next two groups are conducted to evaluate the effect of drying air velocity (1.1-2.5 m/s) and relative humidity (4.6-20.5%), respectively.

The duration of the drying experiments are obtained between 140-380 min. The results indicate that increasing air temperature and velocity and decreasing relative humidity of air reduces drying time.

Drying rate curves indicated that drying process takes place mostly in the falling rate period except very short unsteady-state initial and constant rate periods. Two well-defined falling rate periods are observed. When the temperature is increased and the velocity is decreased, effective diffusion coefficients generally increase.

In consequence, with a view of drying time and product quality, drying air temperatures of 53.3^{O}C, velocity of 2.5 m/s and relative humidity of 20.5% are determined as the best experimental conditions among the others investigated in this study. It should be noticed that the best values obtained are the upper limits of the experimental conditions. To be able to evaluate the wider range, the upper limit should be extended for further experiments.

ISSN 2229-5518

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