Experimental and Comparison Studies on Drying Characteristics of Red Chillies in a Solar Tunnel Greenhouse Dryer and in the Open Sun Drying Method

S. Arun, N. Yashwanth, R. Adharsh

Abstract*— A natural convection solar tunnel dryer was designed and developed for carrying out the experimental and comparison studies of drying characteristics of red chillies during the month of April, 2014 in Negamam region of Pollachi, Tamil Nadu (India). About 50 kgs of red chillies were loaded into the dryer and is repeated for three trails. The drying parameters such as drying time and product quality were taken into account to find out the best drying method for red chillies. The red chillies which has an initial moisture content of 72.98% (w.b.) was reduced to a final moisture content of 7.5% (w.b.) over a time period of 56 hours in the solar tunnel greenhouse dryer whereas the open sun drying method took 122 hours for reducing the moisture content of red chillies to the same level. Also, the quality of red chillies produced from the solar tunnel greenhouse dryer was found to be superior to that of the open sun drying method.

***Index Terms*—Drying time, moisture content, open sun drying, product quality, red chillies, solar tunnel greenhouse dryer.**

I. INTRODUCTION

Chilli is a commercial crop in India. The major chilli producing states in India are Tamil Nadu, Andhra Pradesh, Maharashtra and Karnataka. India is the world's largest producer, consumer and exporter of chillies. In tropical and subtropical countries, red chillies are an unavoidable course in their spicy diet. It is a main ingredient in cooking as it has high nutritional value. Moreover, red chillies are a good source of antioxidants that are rich in vitamins A and C, minerals and other photo-chemicals, which are an important source of nutrients in the human diet. Red chillies are highly perishable agricultural crop and it often leads to the spoilage and wastage of red chillies. The farmers are meeting high demands from the market both in terms of quality and quantity which they could not afford due to the spoilage of products. Furthermore, the small scale farmers cannot meet their estimated profit due to the absence of prevention of wastage of food stuffs. To avoid the spoilage and wastage of food stuffs, the moisture content of the red chillies should be reduced from initial moisture content of 72.98% (w.b.) to a final moisture content of 7.52% (w.b.). Drying is one of the oldest methods of food preservation techniques known to man and the moisture removal process (dehydration) can be done by drying. The traditional method of drying is the open sun drying (OSD) method where the products will be spread over the floor of the drying yard, open to the atmosphere. However, this OSD requires hands on skill persons to carry out the process. Moreover, the moisture removal rate is lower in this open sun drying method which leads to the extended drying time and poor quality of dried products due to the bacterial and fungal infections. To overcome the practical difficulties of OSD, a natural convection solar tunnel greenhouse dryer was designed and developed in Negamam region of Pollachi (Tamil Nadu), India which basically operates on the principle of greenhouse effect in which all the radiations emitted by sun will be absorbed by this dryer since it will be wrapped with the polyethylene sheet of 200 microns that enhances the greenhouse effect. The radiations absorbed will not be emitted back and thus acts as a solar trap. This solar trap is responsible for the steady increase of temperature inside the dryer. A greenhouse heating system is used to increase the thermal energy storage inside the greenhouse during the day or to transfer excess heat from inside the greenhouse to the heat storage area. This heat is recovered at night to satisfy the heating needs of the solar tunnel greenhouse dryer. Also this dryer helps in drying the products at an earlier time than the open sun drying method thereby minimizing drying time. The reduced drying time in the dryer is achieved by maintaining high temperature and low relative humidity inside the dryer as a result of greenhouse effect. Further, the quality of red chillies obtained from the solar tunnel greenhouse dryer was found to be superior to that of open sun dried red chillies as the former is free from quality degrading factors such as infections by fungus & bacteria, damage by birds and animals, etc.

This study was undertaken to experimentally study and compare the drying characteristics of red chillies in the solar tunnel greenhouse dryer and in the open sun drying method and also to find out the best drying method for the drying of red chillies.

II. EXPERIMENTAL PROCEDURE

Experiments were carried out under meteorological conditions of Pollachi (latitude, 10.39°N; longitude, 77.03°E) in India during the month of April, 2014. On the basis of measurement, sunshine duration at this location was measured to be about 11 h per day.

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However, potential sunshine duration is only 8 h per day (9.00 am- 5.00 pm) based on higher solar intensity.

III. SOLAR TUNNEL GREENHOUSE DRYER (STD)

An STD (Fig.1) as a community model solar tunnel greenhouse drier [4 m (W) x 10 m (L) x 3 m (H) at centre] was designed and constructed at Negamam village using locally available materials. Semicircular portion of drier was covered with UV (200µ) stabilized polyethylene film. No post was used inside the greenhouse, allowing a better use of inside space. Three exhaust vents with adjustable butterfly valves were provided at roof top. Inside drier, cement flooring was coated with black paint to improve its performance. STD is provided with metallic racks for keeping the products in layers for drying. To investigate the influence of parameters affecting the performance of solar tunnel drier, various measuring devices were installed. A pyranometer was used to

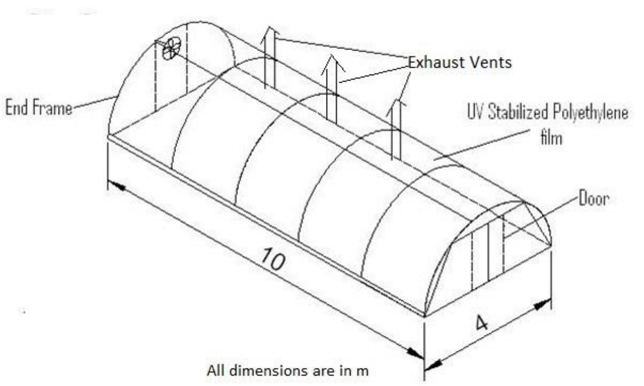

Fig. 1 Solar tunnel greenhouse dryer

Measure the incident solar radiation falling on the roof of the solar tunnel green house dryer. Thermocouples were used to measure air temperature at four different points inside the dryer and ambient air. To measure the relative humidity of the air, a hygrometer was employed. The electric signals from the thermocouples and the pyranometer were recorded with an 8-channel data logger. A sling psychrometer was also used to measure the dry bulb temperature and wet bulb temperature of the air.

IV. INSTRUMENTATION

Figures Calibrated thermocouples (8 numbers, PT 100, uncertainty ±1%) were fixed at different locations inside drier to measure air temperature. Humidity sensors (4 numbers, uncertainty ±1%) were placed at different locations inside drier for measuring air humidity. Ambient humidity was calculated based on measured values of wet and dry bulb temperatures, using two calibrated thermometers, one covered with wet cloth. A solar intensity meter (Delta Ohm, Italy; uncertainty, ±10%) was used to measure instantaneous solar radiation. All temperature sensors, humidity sensors and solar intensity meter were connected to a computer through a data logger (Simex, Italy). Air velocity at drier exit was measured by using a vane type thermo-anemometer (Equinox, Germany; uncertainty ± 0.1%) was used for weighing samples.

V. PRINCIPLE OF SOLAR TUNNEL GREENHOUSE DRYER

The solar radiation is transmitted into the drying chamber by the UV stabilized polyethylene film which provides the greenhouse effect. This film allows all the outside solar radiations to pass into the drying chamber and prevent the re radiation from the drying chamber to the outside and there by helps to accumulating the heat inside the drying chamber. Therefore, the temperature inside the drier is always more than the ambient temperature. This will helps to remove the moisture content of the product placed inside the dryer and therefore it gets dried.

VI. EXPERIMENTAL PROCEDURE

Experiments were conducted during 1-3rd of April 2014 under meteorological conditions of Pollachi, India. Matured and good quality red chillies were loaded into the dryer. Initial moisture content was calculated by taking 10 different samples from different locations. Fresh red chillies were loaded over the trays (porosity 90%) of drier unit. Then, exhaust vents were opened to exhaust initial high humid air. Solar intensity, ambient wet and dry bulb temperatures were measured every 1 h interval till end of drying.

VII. DATA ANALYSIS

A. Determination of Moisture Content

About 10 g samples were chopped from randomly selected five red chillies and kept in a convective electrical oven, maintained at 105 ± 1^{o}C for 5 hrs. Initial (m_i) and final mass (m_f) at time (t) of samples were recorded using electronic balance and repeated every 1 h interval till the end of drying. Moisture content on wet basis (M_{wb}) is defined as

$$M_{wb} = (m_i - m_f) / m_i$$

where, m_i and m_f are initial and final weight of samples respectively.

VIII. RESULTS AND DISCUSSIONS

B. Variation of solar intensity and temperature with time

The fig.2 shows the variation of solar intensity, ambient temperature and dryer temperature during the experimental period (1-3rd April, 2014). During the first day of the experiment, the solar intensity varied between 288 W/m^2 and 799 W/m^2, the ambient temperature varied between 30°C and 38°C with a peak value of 38°C at around 1.00 p.m. and the dryer temperature varied between 41°C and 63°C with a peak value of 63°C at around 1.00p.m. During the second day of the experiment, the solar intensity varied between 298 W/m^2 and 782 W/m^2, the ambient temperature varied between 28°C and 39°C with a peak value of 39°C at around 1.00 p.m. and the dryer temperature varied between 40°C and 63°C with a peak value of 63°C at around 1.00p.m. During the third day of the experiment, the solar intensity varied between 268 W/m^2 and 802 W/m^2, the ambient temperature varied between 27.5°C and 40°C with a peak value of 40°C at around 1.00 p.m. and the dryer temperature varied between 40°C and 63°C with a peak value of 63°C at around 1.00p.m. It is clear from the figure that the dryer temperature was 13°C to 20°C more than the ambient temperature in all the three days of experiment which shows that the dryer temperature got increased effectively due to the green house effect. This increase in temperature helps the dryer to dry products (red chillies) at an earlier time than the open sun drying method. Also, the drier temperature varied according to the solar intensity during this experimental period. The maximum solar radiation observed was about 802 W/m^2.

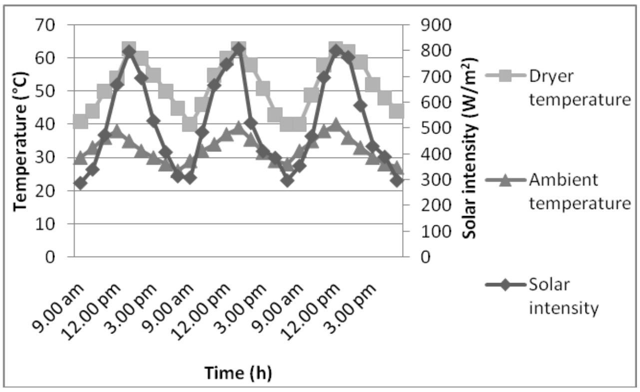

Fig. 2 Variation of solar intensity and temperature with time

C. Variation of relative humidity with time

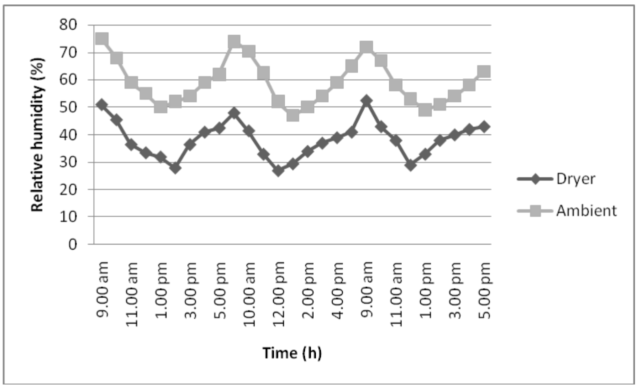

Fig. 3 Variation of relative humidity with time

The fig.3 shows the variation of dryer relative humidity and ambient relative humidity during the experimental period. During the first day of the experiment, the relative humidity of the dryer varied between 28% and 51% whereas the ambient relative humidity varies between 50% and 75%. During the second day, the relative humidity of the dryer varied between 27% and 48% whereas the ambient relative humidity varied between 47% and 74%. During the third day, the relative humidity of the dryer varied between 29% and 52.5% whereas the ambient relative humidity varied between 49% and 72%. In all the three days of the experimental period, the relative humidity of the dryer was found to be less than that of ambient relative humidity due to the high temperature prevailing inside the dryer (due to the green house effect). This high temperature in the dryer is responsible for drying the products (red chillies) at a quicker time than the open sun drying method. Thus the drying time of red chillies is found to be less in case of solar tunnel greenhouse dryer.

D. Variation of velocity with time

The fig.4 shows the variation of ambient air velocity and dryer air velocity during the experimental period. During the first day of experiment, the ambient air velocity varied between 1.6 m/s and 2.8 m/s whereas the dryer air velocity varied between 1 m/s and 1.8 m/s. During the second day of the experiment, the ambient air velocity varied between 2.5 m/s and 3.8 m/s whereas the dryer air velocity varied between 1.5 m/s and 2.8 m/s. During the third day of the experiment, the ambient air velocity varied between 1.8 m/s and 3.2 m/s whereas the dryer air velocity varied between 1.2 m/s and 2.5 m/s. It was evident that the dryer air velocity is lesser than the ambient air velocity due to the buoyancy effect inside the dryer. This is the reason for the lower air velocity and increased drying rate inside the dryer.

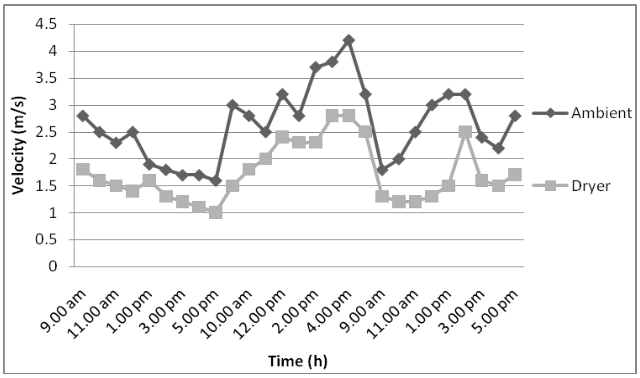

Fig. 4 Variation of velocity with time

E. Variation of moisture content with time

The fig.5 shows the variation of moisture content of red chillies dried inside the dryer and in the open sun during the experimental period. During the first day of the experiment, the moisture content of the red chillies inside the dryer reduced from72.98% to 49.38% whereas for the red chillies dried in open sun drying method, it is reduced from 72.98% to 58.5%. During the second day of the experiment, the moisture content of the red chillies inside the dryer reduced from 49.38% to 25.13% whereas for the red chillies dried in the open sun drying method, it is reduced from 58.5% to 46.3%. During the third day, the moisture content of the red chillies inside the dryer reduced from 25.13% to 7.5% whereas for the red chillies dried in the open sun drying method, it is reduced from 46.3% to 33.5%. By the end of third day, the moisture content of the red chillies inside the dryer was reduced to 7.5% which was the maximum level of moisture removal from red chillies for its safer storage without spoilage and also for cooking purposes. During the fourth day and fifth day of the experiment, the moisture content of red chillies dried in open sun drying method, reduced from 33.5% to 22.02% and from 22.02% to 10.98% respectively.

During the sixth day, the moisture content of the red chillies dried in open sun drying method, reduced from 10.98% to 7.5% which is the maximum rate of moisture removal from the red chillies. In the open sun drying, the products which has an initial moisture content of 72.98%, is reduced to 7.5% for time period of 122 hours, while in the solar tunnel dryer, the products which has an initial moisture content of 72.98%, is reduced to 7.5% for time period of 56 hours.

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It is evident from the fig.5, that the solar tunnel dryer dried the red chillies at an earlier time than the open sun drying method which is basically due to the high temperature and low relative humidity prevailed inside the dryer as a result of greenhouse effect. Also, in the solar tunnel greenhouse dryer there would not be any degradation in quality of red chillies that can be caused by contamination, damage be birds and animals, windborne problems like dust & dirt and infections by fungus and bacteria which were seen predominantly in the open sun dried red chillies.

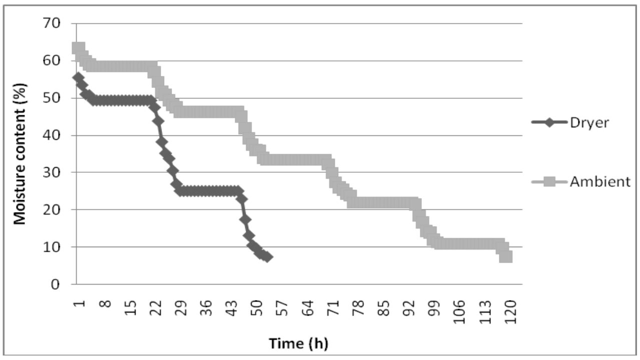

Fig. 5 Variation of moisture content with time

IX. CONCLUSION

Experiment was carried out in a natural convection solar tunnel dryer situated at Negamam village of Pollachi, Tamil Nadu (India) for carrying out the experimental and comparison studies on drying characteristics of red chillies during the month of April, 2014. Three trails of 50 kgs of red chillies were carried out in the dryer. It was found that the red chillies which has an initial moisture content of 72.98% (w.b.) was reduced to a final moisture content of 7.5% (w.b.) over a time period of 56 hours in the solar tunnel greenhouse dryer whereas the open sun drying method took 122 hours for reducing the moisture content of red chillies to the same level. The reduced drying time in the solar tunnel greenhouse dryer is primarily due to the high temperature and low relative humidity inside the dryer which was maintained steadily as a result of greenhouse effect.

Fig.6 Comparison of red chillies dried in the open sun drying method and in solar tunnel greenhouse dryer

The fig.6 shows the comparison of open sun dried and solar tunnel dried red chillies during the experimental period. The red chillies dried in the open sun drying method were found to be degraded in its quality since the chillies were infected by fungus and bacteria, damaged by birds and animals contaminated by insects, and carried away by windborne activities like dust & dirt. But in the solar tunnel greenhouse dryer, the quality deteriorating factors cannot affect the products since the dryer will be having high temperature and low relative humidity inside the dryer which will be sufficient enough to maintain a healthy drying. Thus the solar tunnel greenhouse dryer proves to be producing red chillies of superior quality to that of open sun drying method. Therefore, the red chillies can be effectively dried in the solar tunnel greenhouse dryer than in the open sun drying method due to the reduced drying time and superior quality than the open sun drying method (Fig.6).

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