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

S. Arun, K. Vinoth Kumar, R. Adharsh

Abstract— A natural convection solar tunnel greenhouse dryer was designed and developed in Pollachi region of Tamil Nadu (India) for studying and comparing the drying characteristics of grapes with the open sun drying method during the month of April, 2014. About 30 kgs of grapes were loaded into the dryer and it was repeated for three trails. The drying time and product quality were the main drying parameters which are taken into account. The grapes which has an initial moisture content of 80% was reduced to 10% in solar tunnel greenhouse dryer over a time period of 55 hours whereas the grapes dried in the open sun drying method took 149 hours for the reducing the moisture content of the grapes to the same level. The high temperature and low relative humidity inside the solar tunnel greenhouse dryer helps the dryer to dry the grapes at an earlier time than the open sun method. Also, the greenhouse effect is responsible for the high temperature and low relative humidity inside the dryer that prevents fungal and bacterial infections, damage by birds and animals, etc. which ensures the production of superior quality of grapes in the dryer than in the open sun drying method.

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

I. INTRODUCTION

Grapes are well known for its medicinal properties and are grown under a variety of soil and climatic conditions in three distinct agro-climatic zones in India. The total world production of grapes is estimated to be about 63 million tonnes, which amount to about 16% of total fruit production. About 20% of the table grape production is exported as compared to 9% export of other fruits. The area, production and the productivity of grapes in India is 42,600 ha, 1.1 million tonnes and 25.4 tonnes/ha, respectively (Anonymous, 2003). Among fruits, grapes are the most perishable food stuffs, when compared with other agricultural products. They can easily get affected by microorganism resulting in poor quality which ultimately leads to wastage of food stuffs. In order to avoid the wastage and to prolong the shelf life of grapes, the moisture content of grapes can be reduced from an initial moisture content of 80% (w.b.) to a final moisture content of 10% (w.b.). These dehydration techniques should be cautiously carried out by experts as it has possibility of affecting the texture and colour of the grapes.

Dried grapes are a source of carbohydrates and it contains large amounts of iron, vitamins and minerals which will be usually included in breakfast cereals, dairy and bakery. The oldest method of drying agricultural products is by traditional open sun drying method where the products will be spread over the huge drying yard allowing drying. This method of drying was found to be ineffective and a time consuming process since this method has high relative humidity in atmosphere that delays drying of products to a greater extent. Also, the products dried in this method were found to be deteriorated by infections from fungus and bacteria, damaged by rodents and birds, etc. To overcome the practical difficulties of open sun drying, a natural convection solar tunnel dryer was designed and fabricated in Negamam region of Pollachi, Tamil Nadu (India). This dryer 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. Various studies have been reported on drying of grapes in solar tunnel greenhouse dryer [1]-[5]. 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 grapes obtained from the solar tunnel greenhouse dryer was found to be superior to that of open sun dried grapes 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 investigate the experimental and comparison studies on drying characteristics of grapes in a solar tunnel greenhouse dryer and in open sin drying method and also to find out the best drying method for drying of grapes in terms of product quality and drying time.

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II. EXPERIMENTAL SECTION

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. 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

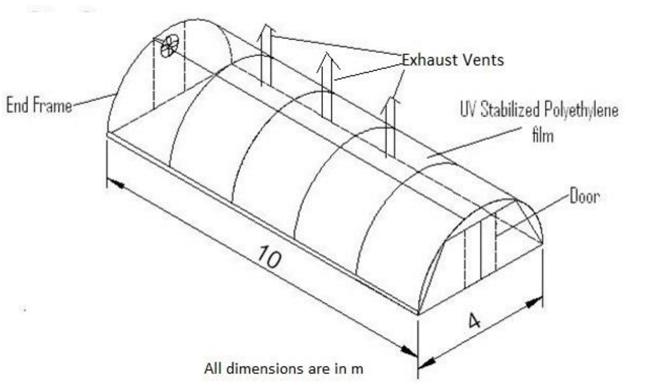

Fig. 1 Solar Tunnel Greenhouse Dryer

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 13-15th of April 2014 under meteorological conditions of Pollachi, India. Matured and good quality grapes were loaded into the dryer. Initial moisture content was calculated by taking 10 different samples from different locations. Fresh grapes 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 cups 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 (13-15th April, 2014). During the first day of the experiment, the solar intensity varied between 323 W/m^2 and 727 W/m^2, the ambient temperature varied between 29°C and 37°C with a peak value of 37°C at around 1.00 p.m. and the dryer temperature varied between 40°C and 62°C with a peak value of 62°C at around 1.00p.m. During the second day of the experiment, the solar intensity varied between 325 W/m^2 and 757 W/m^2,

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the ambient temperature varied between 30°C and 39°C with a peak value of 39°C at around 1.00 p.m. and the dryer temperature varied between 42°C and 62°C with a peak value of 62°C at around 1.00p.m. During the third day of the experiment, the solar intensity varied between 287 W/m^2 and 792 W/m^2, the ambient temperature varied between 28°C and 37°C with a peak value of 37°C at around 1.00 p.m. and the dryer temperature varied between 40°C and 67°C with a peak value of 67°C at around 1.00p.m. It is clear from the figure that the dryer temperature was 15°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 (grapes) 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 792 W/m^2.

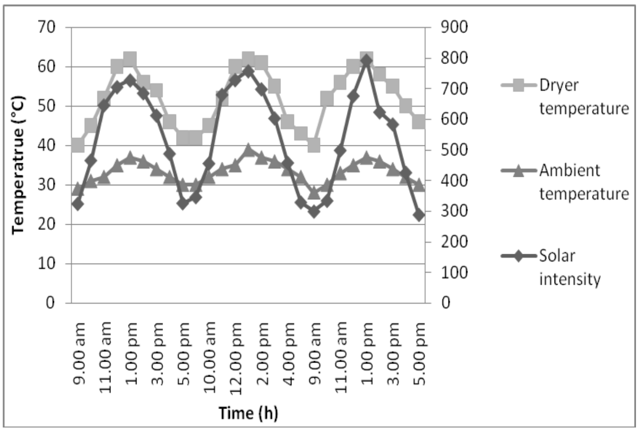

Fig. 2 Variation of Solar Intensity and Temperature with Time

C. 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 29% and 50% whereas the ambient relative humidity varies between 40 % and 72%.

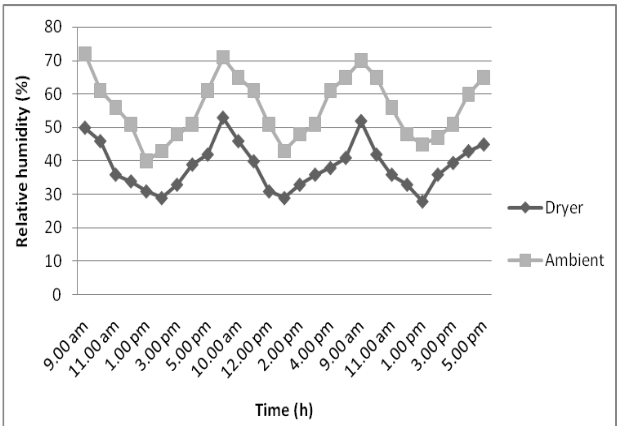

Fig. 3 Variation of Relative Humidity with Time

During the second day, the relative humidity of the dryer varied between 29% and 53% whereas the ambient relative humidity varied between 43% and 71%. During the third day, the relative humidity of the dryer varied between 28% and 52% whereas the ambient relative humidity varied between 45% and 70%. 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 (grapes) at a quicker time than the open sun drying method.

D. Variation of Air Velocity with Time

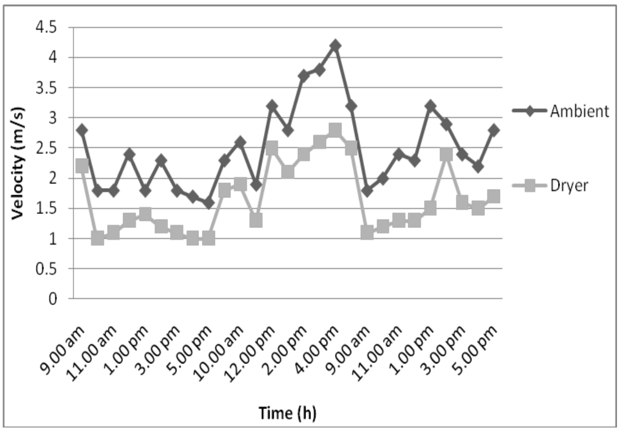

Fig. 4 Variation of Air Velocity with Time

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 2.2 m/s. During the second day of the experiment, the ambient air velocity varied between 1.9 m/s and 4.2 m/s whereas the dryer air velocity varied between 1.3 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 1.1 m/s and 2.4 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.

E. Variation of Moisture Content with Time

The fig.5 shows the variation of moisture content of grapes 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 grapes inside the dryer reduced from 80% to 57.5% whereas for the grapes dried in open sun drying method, it is reduced from 80% to 64.32%. During the second day of the experiment, the moisture content of the grapes inside the dryer reduced from 57.5% to 29.5% whereas for the grapes dried in the open sun drying method, it is reduced from 64.32% to 52.2%. During the third day, the moisture content of the grapes inside the dryer reduced from 29.5% to 10% whereas for the grapes dried in the open sun drying method, it is reduced from 52.2% to 40%. By the end of third day, the moisture content of the grapes inside the dryer was reduced to 10% which was the maximum level of moisture removal from grapes for the safe storage of grapes without spoilage and also for cooking purposes.

During the fourth day and fifth day of the experiment, the moisture content of grapes dried in open sun drying method, reduced from 40% to 29.38% and from 29.38% to 21% respectively. During the sixth and seventh day of the experiment, the moisture content of the grapes dried in open sun drying method, reduced from 21% to 13.12% and from 13.12% to 10% respectively. By the end of the seventh day, the moisture content of the grapes dried in the open sun drying method was reduced to 10% which is the maximum rate of moisture removal from grapes. In the open sun drying, the products which has an initial moisture content of 80%, is reduced to 10% for time period of 149 hours, while in the solar tunnel dryer, the products which has an initial moisture content of 80%, is reduced to 10% for time period of 55 hours. It is evident from the fig.5, that the solar tunnel dryer dried the grapes 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.

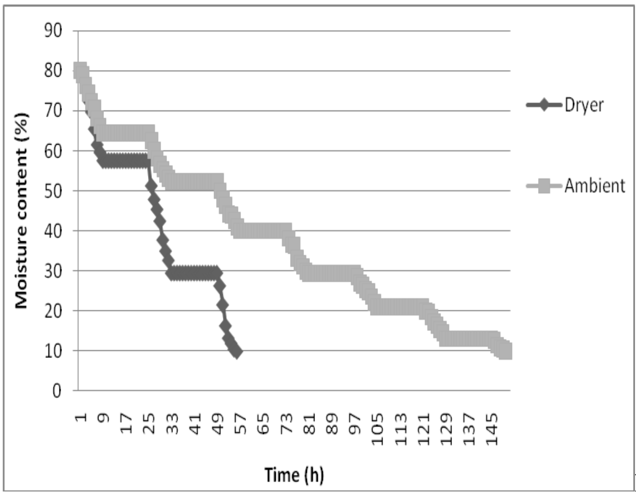

Fig. 5 Variation of Moisture Content with Time

IX. CONCLUSION

Experiments were conducted in a natural convection solar tunnel greenhouse dryer situated at Negamam village of Pollachi, Tamil Nadu (India) for studying and comparing the drying characteristics of grapes with the open sun drying method during the month of April, 2014. Three experimental runs with 30 kgs of grapes were carried out in the dryer. The solar tunnel greenhouse dryer dried the grapes which has an initial moisture content of 80% to a final moisture content of 10% over a time period of 55 hours whereas the open sun drying method took 149 hours for reducing the moisture content of the grapes to the same level.

Fig. 6 Comparison of Solar Tunnel Dried and Open Sun Dried Grapes

The reduced drying time in the solar tunnel greenhouse dryer is primarily due to the greenhouse effect which is responsible for the high temperature and low relative humidity inside the dryer that prevents the bacterial and fungal infections, contamination by insects, windborne problems like dirt & dust and damage by birds & animals. These above said factors are predominant in open sun drying method which degrades the quality of products (grapes) to a greater extent. Thus solar tunnel greenhouse dryer produces grapes of superior quality to the ones produced by open sun drying method (Fig.6). The reduced drying time and superior quality of grapes in the solar tunnel greenhouse dryer proves that this dryer can be utilized for the effective drying of grapes and other products than the open sun drying method.

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