Experimental and Comparison Studies on Drying Characteristics of Red Chillies in a Solar Tunnel Greenhouse Dryer Coupled with and without Biomass Backup Heater

S. Arun, N. Yashwanth

Abstract— A natural convection solar tunnel greenhouse dryer coupled with biomass heater was designed and developed in Nallampalli region of Pollachi, Tamil Nadu (India) and also a natural convection solar tunnel greenhouse dryer without biomass heater was designed and developed in Negamam region of Pollachi, Tamil Nadu (India) for carrying out the experimental and comparison studies of drying characteristics of red chillies during the month of May, 2014. Three experimental runs with about 50kgs of fresh and good quality red chillies were loaded into those two respective dryers. The mass of fuel added to the biomass heater was about 7.5kg/hr. The biomass was ignited for every one hour after 5PM so as to maintain a high temperature inside the dryer. The solar tunnel dryer coupled with the biomass heater dried the red chillies which has an initial moisture content of 72.98% (w.b.) to a final moisture content of 7.5% (w.b.) over a time period of 30 hours whereas the solar tunnel greenhouse dryer without the biomass heater took 56 hours for reducing the moisture content to the same level. The biomass heater is responsible for supplying sufficient heat inside the dryer to maintain a high temperature steadily inside the dryer even during the times when there would be a drop in sunshine (after 5PM). This high temperature and low relative humidity inside the dryer (with biomass heater) accelerated the drying of red chillies which thereby reduces drying time of the red chillies. Also the quality of the red chillies obtained from the solar tunnel greenhouse dryer coupled with biomass heater was found to be superior to that of the red chillies obtained from the solar tunnel greenhouse dryer without the biomass heater which is due to the high temperature and low relative humidity prevailed all the time inside the dryer irrespective of fall in sunshine that prevented the effect of fungal and bacterial infections, damage from birds and animals and windborne problems like dust & dirt.

Index Terms—Biomass heater, drying time, moisture content, open sun drying, product quality, red chillies, solar tunnel greenhouse dryer, sunshine.

I. INTRODUCTION

In tropical and subtropical countries, red chillies are a major ingredient in the day to day meal due to its spiciness. One of the commercial crops in India is red chilli. India is one of the major exporter and importer of red chillies around the world. Tamil Nadu is one of the major red chilli producing state next to Andhra Pradesh, Maharashtra and Karnataka. Apart from this, red chillies are famous for their medicinal benefits too. Red chillies are a good source of antioxidants, vitamins and minerals thus helps in development of human health. Red chillies are highly perishable crop and hence susceptible to spoilage and degradation of quality. The moisture content of the red chillies are to be reduced from an initial moisture content of 72.98% (w.b.) to a final moisture content of 7.5% (w.b.) for avoiding the spoilage of the red chillies. This process of moisture removal is one of the challenging processes which farmers are encountering to avoid spoilage of products. Drying is a promising technique for this moisture removal from the products, being the oldest of food preservation known to man. Several methods of drying were practiced and the most common method of drying still in practice is the Open Sun Drying (OSD) method. In this method, the products will be spread over the huge floor of the drying yard. But this process is a time consuming process and there will be degradation in quality of dried products due to the low atmospheric temperature and high relative humidity of the surrounding air that leads to fungal and bacterial infections, contamination by insects, damage by rodents & birds and windborne problems like dust & dirt. In addition, this OSD method requires a skillful person to carry out the process effectively thus leading to the high labour cost and demand of manpower. To overcome the practical difficulties of OSD method, 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. Moreover, the solar tunnel greenhouse dryer overcomes the effects of bacterial and fungal infections, contamination by insects, damage by birds and animals etc. Also this dryer helps in drying the products at an earlier time than the open sun drying method thereby minimizing drying time. 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.

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But even in this dryer, arises a problem when there was a fall in sunshine. The dryer cannot dry the products effectively after 5PM of a day where there will be a drop in sunshine and temperature. The heat recovery from greenhouse effect during time won't last for a longer time leading to an extended drying time but not more than open sun drying method. In order to overcome this defect, a natural convection solar tunnel greenhouse dryer coupled with biomass heater was designed and developed in Nallampalli village of Pollachi, Tamil Nadu (India). The biomass heater coupled to the dryer will supply sufficient heat for an effective drying of products inside the dryer when there is a fall in sunshine even at night time. The biomass can be ignited with any type of fuel such as coconut fronts, coconut shells, coconut husk etc. and it should be loaded for every one hour interval (after 5PM). By using this type of biomass coupled dryer, the products can be dried yet at an earlier time than the solar tunnel greenhouse dryer without the biomass heater.

This study investigates and compares the drying characteristics of red chillies dried in the open sun drying method and in the solar tunnel greenhouse dryer with and without biomass heater and thereby optimizing the best dryer for drying of products.

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 May, 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. 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 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.

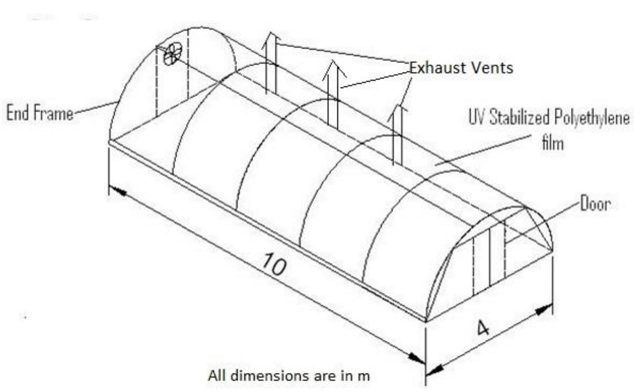

Fig. 1 Solar tunnel greenhouse dryer

IV. SOLAR TUNNEL GREENHOUSE DRYER COUPLED WITH BIOMASS BACKUP HEATER

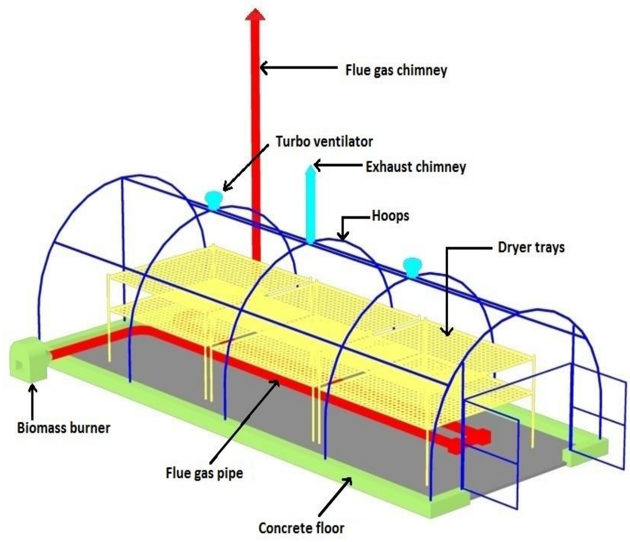

Fig. 2 Solar tunnel greenhouse dryer coupled with biomass backup heater

An STD (Fig.2) 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 Nallampalli village using locally available materials. Both this dryer and the above mentioned dryer works on the principle of greenhouse effect. The only difference from the previous dryer (Fig.1) is that the biomass backup heater coupled to this dryer. The biomass heater can be ignited by any type of fuel such as coconut fronts, coconut shell and coconut husk. The biomass heater should be loaded for every one hour interval so as to provide sufficient heat inside the dryer through the flue gas pipe that runs through the dryer. The flue gas pipes are there to radiate heat to the dryer thereby providing heat to it for the effective drying even at night time and rainy days.

V. 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.

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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.

VI. PRINCIPLE OF SOLAR TUNNEL GREENHOUSE DRYER WITH AND WITHOUT BIOMASS HEATER

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.

VII. EXPERIMENTAL PROCEDURE

Experiments were conducted during 14-16th & 17-19th of May, 2014 for the driers placed at Negamam and Nallampalli village of Pollachi, Tamil Nadu (India) respectively. Matured and good quality red chillies were considered as the drying product for this experiment. Initial moisture content was calculated by taking 10 different samples from different locations inside the drier. Fresh red chillies were loaded over trays (having 90% porosity) of drier unit. Then, the exhaust vents were opened to exhaust initial high humid air. Solar intensity, ambient temperature, dryer temperature and air velocity were measured every 1 h interval till end of drying. During night time (i.e.) in the absence of sun (after 5 PM), to maintain the temperature inside the dryer, biomass such as coconut fronts, coconut husk, coconut shell etc. have been added as a fuel to give heat to solar tunnel dryer. Mass of the fuel added was about 7.5kg/hr and was added for every one hour interval from 5PM (previous day) to 8AM (next day).

VIII. 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.

IX. RESULTS AND DISCUSSIONS

B. Variation of temperature with time

The fig.3 shows the variation of ambient temperature and dryer temperature with and without biomass backup heater over time during the experimental period for carrying out the drying of red chillies. During the first 24 hours of the experiment (first day) in the dryer coupled with biomass heater, the temperature inside the dryer varied between 39°C and 63°C with a peak value of 63°C at around 1.00 p.m. , the ambient temperature varied between 22°C and 39°C with a peak value of 39°C at around 1.00 p.m. whereas for the dryer without the biomass heater, the temperature inside the dryer varied between 41°C and 62°C with a peak value of 62°C at around 1.00p.m., the ambient temperature varied between 26°C and 38°C with a peak value of 38°C at around 1.00 p.m. During the next 24 hours of the experiment (second day) in the dyer coupled with biomass heater, the temperature inside the dryer varied between 38°C and 63°C with a peak value of 63°C at around 1.00 p.m. , the ambient temperature varied between 23°C and 37°C with a peak value of 37°C at around 1.00 p.m. whereas for the dryer without the biomass heater, the temperature inside the dryer varied between 40°C and 63°C with a peak value of 63°C at around 1.00p.m., the ambient temperature varied between 28°C and 39°C with a peak value of 39°C at around 1.00 p.m.

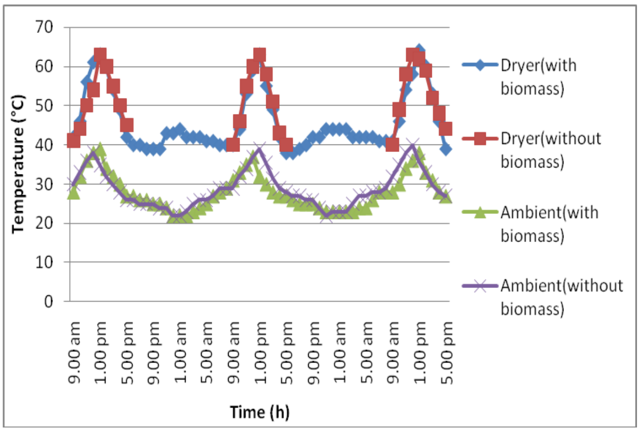

Fig. 3 Variation of temperature with time

During the last 24 hours of the experiment (third day) in the dryer coupled with biomass heater, the temperature inside the dryer varied between 39°C and 64°C with a peak value of 64°C at around 1.00 p.m. , the ambient temperature varied between 27°C and 38°C with a peak value of 38°C at around 1.00 p.m. whereas for the dryer without the biomass heater, the temperature inside the dryer varied between 40°C and 61°C with a peak value of 61°C at around 1.00p.m., the ambient temperature varied between 27.5°C and 40°C with a peak value of 40°C at around 1.00 p.m. It is evident from the figure that the temperature inside the dryer which is coupled with the biomass heater was 3°C to 5°C more than the temperature inside the dryer without the biomass heater in all the three days of the experiment. It also shows that that the temperature inside the dryer which is coupled with the biomass heater was increasing steadily even at the absence of solar radiation (after 5PM) which is due to the effect of biomass backup heater that supplied sufficient heat to the dryer through the flue gas pipes which then radiated into the dryer for quicker drying of products (red chillies). This steady increase in temperature dried the red chillies at a much earlier time than the dryer without the biomass heater and the open sun drying method.

C. Variation of relative humidity with time

The fig.4 shows the variation of relative humidity of the dryer with and without biomass heater over time during the experimental period. During the first 24 hours of the experiment (first day) in the dryer that is coupled with biomass heater, the relative humidity of the dryer varied between 27% and 45%, the ambient relative humidity varied between 48% and 86% whereas for the dryer without the biomass heater, the relative humidity varied between 28% and 51%, the ambient relative humidity varied between 50% and 75%. During the next 24 hours of the experiment (second day) in the dryer that is coupled with biomass heater, the relative humidity of the dryer varied between 29% and 42%, the ambient relative humidity varied between 48% and 86% whereas for the dryer without the biomass heater, the relative humidity varied between 27% and 48%, the ambient relative humidity varied between 47% and 74%.

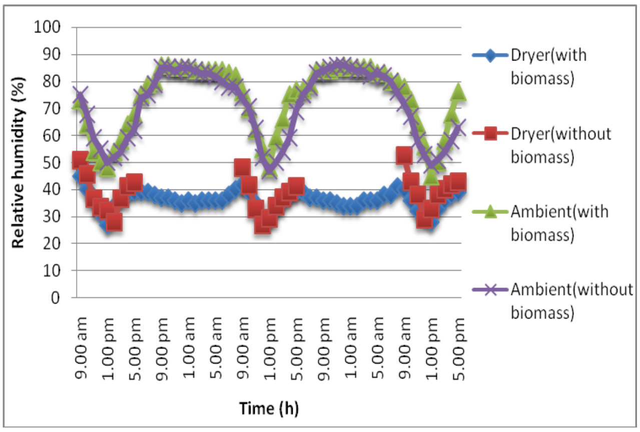

Fig. 4 Variation of relative humidity with time

During the last 24 hours of the experiment (third day) in the dryer that is coupled with the biomass heater, the relative humidity of the dryer varied between 28% and 40%, the ambient relative humidity varied between 45% and 78% whereas for the dryer without the biomass heater, the relative humidity varied between 29% and 53%, the ambient relative humidity varied between 49% and 72%. From the fig.4, it is clear that the relative humidity of the dryer that is coupled with the biomass heater was less when compared with the relative humidity of the dryer without the biomass heater which is primarily due to the prevailing of high temperature inside the dryer all the time even at night time where there will be a drop in sunshine. The high temperature and low relative humidity prevailed inside the dryer due to the effect of biomass heater. This high temperature and thus, low relative humidity that prevailed all the time inside the dryer (with biomass heater), dried the red chillies at a quicker time than the dryer without biomass heater and the open sun drying method.

D. Variation of velocity with time

The fig.5 shows the variations of ambient velocity and the velocities of the dryer with biomass and without biomass heater over time during the experimental period. During the first 24 hours of the experiment (first day) in the dryer that is coupled with the biomass heater, the velocity of air inside the dryer varied between 0.1 m/s and 2.5 m/s and the ambient air velocity varied between 0.5 m/s and 3.5 m/s whereas for the dryer without the biomass heater, air velocity varied between 1 m/s and 1.5 m/s and the ambient air velocity varied between 1.6 m/s and 2.4 m/s. During the next 24 hours of the experiment (second day) in the dryer that is coupled with the biomass heater, the velocity of air inside the dryer varied between 0.1 m/s and 2.5 m/s and the ambient air velocity varied between 0.8 m/s and 3 m/s whereas for the dryer without the biomass heater, air velocity varied between 1.2 m/s and 2.3 m/s and the ambient air velocity varied between 1.9 m/s and 3.8 m/s. During the last 24 hours of the experiment (third day) in the dryer that is coupled with the biomass heater, the velocity of air inside the dryer varied between 1.1 m/s and 2.4 m/s and the ambient air velocity varied between 1.5 m/s and 2.9 m/s whereas for the dryer without the biomass heater, air velocity varied between 1.1 m/s and 1.9 m/s and the ambient air velocity varied between 1.8 m/s and 3.3 m/s.

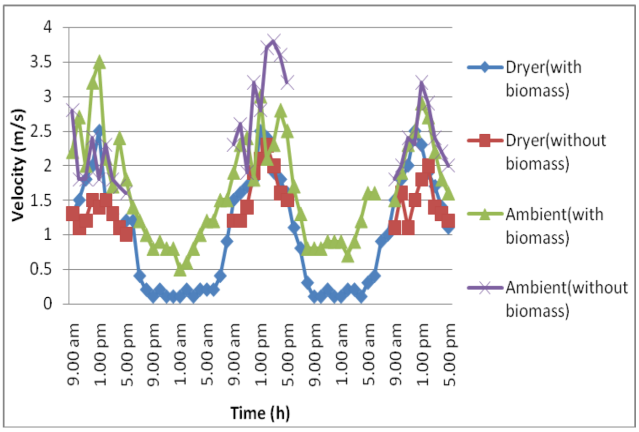

Fig. 5 Variation of velocity with time

It can be clearly seen that the air velocity inside the dryer that is coupled with the biomass heater was more than the air velocity inside the dryer that is without the biomass heater which is due to the high temperature prevailed all the time inside the dryer (with biomass heater) even during the night time. This increase in air velocity makes the products (red chillies) to dry at an earlier time than the open sun drying method and the dryer without the biomass heater.

E. Variation of sheet temperature with time

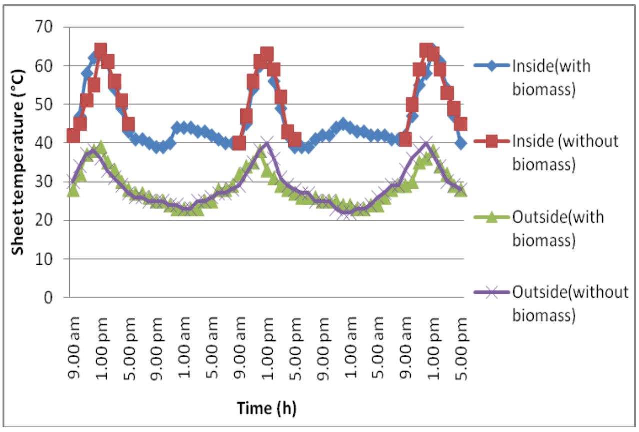

Fig. 6 Variation of sheet temperature with time

The fig.6 shows the variations of sheet temperature inside and outside the dryer (with and without biomass heater) over time during the experimental period. During the first 24 hours of the experiment (first day), the sheet temperature inside the dryer varied from 39°C and 63°C, the sheet temperature outside the dryer varied from 23°C and 39°C whereas for the dryer without the biomass heater, the sheet temperature inside the dryer varied from 42°C and 64°C, the sheet temperature outside the dryer varied from 27°C and 38°C. During the next 24 hours of the experiment (second day), the sheet temperature inside the dryer varied from 39°C and 64°C, the sheet temperature outside the dryer varied from 22°C and 38°C whereas for the dryer without the biomass heater, the sheet temperature inside the dryer varied from 40°C and 62°C, the sheet temperature outside the dryer varied from 28°C and 40°C. During the last 24 hours of the experiment (third day), the sheet temperature inside the dryer varied from 40°C and 64°C, the sheet temperature outside the dryer varied from 28°C and 38°C whereas for the dryer without the biomass heater, the sheet temperature inside the dryer varied from 41°C and 63°C, the sheet temperature outside the dryer varied from 28°C and 40°C. It is evident that the sheet temperature inside the dryer that is coupled with the biomass heater was more than the sheet temperature inside the dryer without the biomass heater which is due to the effect of biomass heater coupled to the dryer. As a result of this biomass heater, there was a steady increase in the temperature inside the dryer even when there is a fall in sunshine (after 5PM) which is responsible for the earlier drying of red chillies in the dryer (with biomass heater) than that of the dryer without the biomass heater and the open sun drying method.

F. Variation of floor temperature with time

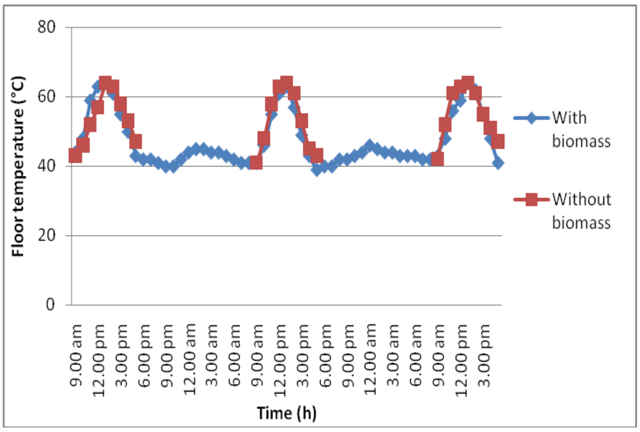

Fig. 7 Variation of floor temperature with time

The fig.7 shows the variation of floor temperature of the dryer with and without the biomass heater over time during the experimental period. During the first 24 hours of the experiment (first day) in the dryer that is coupled with the biomass heater, the temperature of the floor inside the dryer varied from 40°C and 64°C whereas for the dryer without the biomass heater, the temperature of the floor inside the dryer varied from 43°C and 65°C. During the next 24 hours of the experiment (second day) in the dryer that is coupled with the biomass heater, the temperature of the floor inside the dryer varied from 39°C and 63°C whereas for the dryer without the biomass heater, the temperature of the floor inside the dryer varied from 41°C and 63°C. During the last 24 hours of the experiment (third day) in the dryer that is coupled with the biomass heater, the temperature of the floor inside the dryer varied from 41°C and 64°C whereas for the dryer without the biomass heater, the temperature of the floor inside the dryer varied from 42°C and 64°C. From the figure, it is clear that the floor temperature of the dryer that is coupled with the biomass heater is more than the floor temperature of the dryer without the biomass heater which is primarily due to the effect of biomass heater that steadily increased the temperature inside the dryer even after the fall in sunshine (after 5PM). Thus this has paved the way for the earlier drying of red chillies inside the dryer (with biomass heater) than that of the dryer without biomass heater and the open sun drying method.

G. Variation of product temperature with time

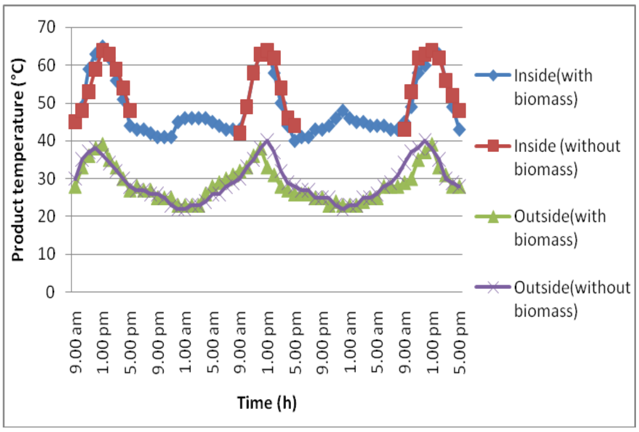

Fig. 8 Variation of product temperature with time

The fig.8 shows the variation of product temperature inside and outside the dryer (with biomass and biomass heater) over time during the experimental period. During the first 24 hours of the experiment (first day), the product temperature inside the dryer varied from 41°C and 65°C, the product temperature outside the dryer varied from 23°C and 39°C whereas for the dryer without the biomass heater, the product temperature inside the dryer varied from 45°C and 64°C, the product temperature outside the dryer varied from 28°C and 38°C. During the next 24 hours of the experiment (second day), the product temperature inside the dryer varied from 40°C and 64°C, the product temperature outside the dryer varied from 23°C and 41°C whereas for the dryer without the biomass heater, the product temperature inside the dryer varied from 42°C and 64°C, the product temperature outside the dryer varied from 28°C and 40°C. During the last 24 hours of the experiment (third day), the product temperature inside the dryer varied from 43°C and 64°C, the product temperature outside the dryer varied from 28°C and 39°C whereas for the dryer without the biomass heater, the product temperature inside the dryer varied from 43°C and 63°C, the product temperature outside the dryer varied from 28°C and 40°C. It is evident that the temperature of the product inside the dryer that is coupled with the biomass heater was more than that of the dryer without the biomass heater which shows that the high temperature prevailed inside the dryer (with biomass heater) all the time irrespective of drop in sunshine (after 5PM). Also, the products obtained from the dryer that is coupled with the biomass heater, was found to be free from fungal and bacterial infections, damage by rodents, insects and birds, and windborne problems like dirt & dust and thus superior quality red chillies can be obtained from the dryer that is coupled with the biomass heater than that of the open sun drying method and the dryer without the biomass heater.

H. Variation of moisture content with time

The fig.9 shows the variation of moisture content of the red chillies dried under the open sun drying method and inside the dryer with biomass and without biomass heater over time during the experimental period. During the first 24 hours of the experiment (first day) in the dryer that is coupled with the biomass heater, the moisture content of the red chillies inside the dryer reduced from 72.98% to 28.69% and the moisture content of the open sun dried red chillies reduced from 72.98% to 57.44% whereas for the dryer without biomass heater, the moisture content of the red chillies inside the dryer reduced from 72.98% to 49.38% and the moisture content of the open sun dried red chillies reduced from 72.98% to 58.5%. During the next 24 hours of the experiment (second day) in the dryer without the biomass heater, the moisture content of the red chillies inside the dryer reduced from 28.69% to 7.52% and the moisture content of the open sun dried red chillies reduced from 57.44% to 44.32%. By the mid of second day, the moisture content of the red chillies in the solar tunnel greenhouse dryer that is coupled with the biomass heater was reduced to 7.52% which is the maximum rate of moisture removal from the red chillies over a time period of 30 hours and is the optimum level of moisture content for the process of safe storage and to use as a spicy product in culinary purposes whereas the open sun drying method took 102 hours for the reduction of moisture content of the red chillies to the same level.

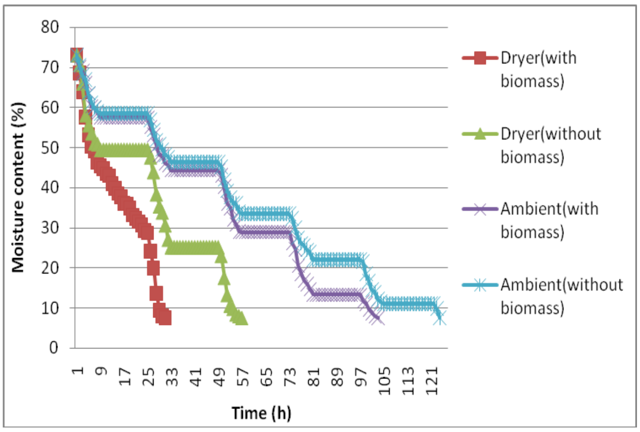

Fig. 9 Variation of moisture content with time

During the third day of the experiment, the moisture content of the red chillies inside the dryer without the biomass heater reduced from 25.13% to 7.5% and the moisture content of the open sun dried red chillies reduced from 46.3% to 33.5%. By the end of third day, the moisture content of the red chillies inside the dryer with the biomass heater, is reduced to 7.5% in 56 hours, which is the maximum rate of moisture content that can be removed from the red chillies whereas the open sun drying method took 123 hours for the reduction of moisture content of the red chillies to the same level. It is evident from the fig. that the solar tunnel greenhouse dryer coupled with the biomass heater took only 30 hours for reducing the moisture content of the red chillies from 72.98% to 7.5% whereas the dryer without the biomass heater took 56 hours for reducing the moisture content of the red chillies to the same level. This shows that the dryer coupled with the biomass heater is more efficient in drying the products at a quicker time which is mainly due to the effect of biomass heater. The high temperature and the low relative humidity inside the dryer that prevailed all the time irrespective of the drop in sunshine level (after 5PM) is primarily responsible for the quicker drying time inside the dryer. Also, this paved the way for the higher rate of moisture removal from the red chillies in the dryer that is coupled with the biomass heater than that of the open sun drying method and the dryer without biomass heater.

X. CONCLUSION

Experiments were conducted in a natural convection solar tunnel greenhouse dryer coupled with biomass heater situated at Nallampalli village of Pollachi, Tamil Nadu (India) and also in a natural convection solar tunnel greenhouse dryer without biomass heater situated at Negamam village of Pollachi, Tamil Nadu (India) during the month of May, 2014 in order to compare and study the drying characteristics of red chillies in the respective dryers and also to find out the best drying method for drying of red chillies. About 60 kgs of fresh and matured red chillies were loaded into the dryers and is repeated for three trails. The mass of fuel added (after 5PM) to the biomass heater was about 7.5kg/hr. The biomass heater was ignited for every one hour and the fuel added was the remains from the coconuts such as coconut shell, coconut husk, coconut fronts and also firewood. The red chillies which has the initial moisture content of 72.98% (w.b.) was reduced to 7.5% (w.b.) over a time period of 30 hours in the solar tunnel greenhouse dryer coupled with biomass heater whereas the dryer without the biomass heater took 56 hours for reducing the moisture content of the red chillies to the same level.

Fig. 10 Drying of red chillies in the solar tunnel greenhouse dryer coupled with the biomass heater

The fig.10 shows the drying of red chillies dried in the solar tunnel greenhouse dryer coupled with the biomass heater situated at Nallampalli village of Pollachi region. The reduced drying time in the solar tunnel greenhouse dryer that is coupled with the biomass heater is due to the high temperature and low relative humidity prevailed all the time inside the dyer even when there was a fall in sunshine (after 5PM). This high temperature and low relative humidity of the dryer (with biomass heater) is due to the effect of biomass heater and the greenhouse effect which as a whole dried the red chillies at an earlier time than the dryer without biomass heater and the open sun drying method. The drying time of red chillies in the solar tunnel greenhouse dryer coupled with the biomass heater is less than the drying time of the red chillies in the dryer without biomass heater and the open sun drying method which is primarily due to the effect of biomass heater coupled to the dryer. Also, the quality of red chillies obtained from the dyer coupled with biomass heater was found to be of superior quality than that of the red chillies obtained from the dryer without the biomass heater. Thus, the solar tunnel greenhouse dryer coupled with the biomass heater proves to be more efficient in drying red chillies in terms of drying time and product quality.

Fig. 11 Comparison of red chillies dried in the open sun drying method and in the solar tunnel greenhouse dryer with biomass heater

Fig. 12 Comparison of red chillies dried in the open sun drying method and in the solar tunnel greenhouse dryer without the biomass heater

The Fig.11 & 12 shows the comparison of red chillies dried in the open sun drying method and in the solar tunnel greenhouse dryer coupled with and without biomass heater. Also, it was found out that the solar tunnel dryer coupled with the biomass heater is more effective in drying the red chillies at reduced drying time and superior quality.

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