Experimental Methodology of Advanced Green House Solar Dryer by Evaluating the Temperature Distribution and Mass Transfer

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Abstract- *The geothermal energy has finite use; biomass and other derivatives (wood and charcoal) are highly efficient in comparison with other energy sources still with dwindling sources of biomass there is need to find alternatives. On top of this there is continuously pollution growth, resources depletion and climate change due to continuous use of conventional fuels. The earth and its atmosphere absorb 3.8×10^{24} J/yr of incoming solar energy. In the solution of energy needs, solar inform of renewable energy source can play a very important role. Cost effectiveness of many renewable sources including solar has been improved there through research and technological developments. It is expected that about middle of this century half of the world's energy needs is likely to be met by the renewable energy and mainly solar energy.*

Keywords- Solar Thermal Conversion, Green House Dryer, Solar Radiation, Forced Convection.

I. INTRODUCTION

The solar energy can be utilized in two ways, directly and indirectly. Direct utilization of solar energy includes thermal and photovoltaic conversion. Indirect utilization includes the use of wind, biomass, wave energy, temperature difference in the ocean and marine currents. In solar thermal conversion system, the energy is firstly collected by using solar pond, a flat plate collector, heliostats (turbine mirrors) or focusing collector. Solar thermal power cycle is classified in three cycles as low, medium and high temperature cycles depending on temp range. The solar energy is directly converted into heat energy by solar collectors. In photovoltaic conversion in solar cells the solar energy. In the field of agriculture solar dryers are most viable method of preserving food product. A cost-effective advanced greenhouse solar dryer has been constructed in this research work and temperature [1-3].

Drying is one of the most efficient methods used to preserve food products for longer periods. A solar dryer is an enclosed unit, to keep the food safe from damage, birds, insects, and unexpected rainfall. The food is dried using solar thermal energy in a cleaner and healthier way. The dryer that has been reconstructed is a mixed mode solar cabinet dryer wherein the blended motion of solar radiation incident on the fabric to be dried and the air preheated in the sun collector offer the warmth required for the drying operations. Here the atmospheric air enters via inlet portion of the sun collector at the lowest give up and the moisten air get exhaust through the outlet element. The goal of the dryer is mainly for the welfare of the marginalized and poor farmers those who can't afford hi-tech facilities and equipment's to preserve their agricultural products and to eliminate the unwanted and unpredictable food spoilage due to lack of facilities in the region [4-7].

II. SOLAR DRYING SYSTEM

(a) Working Principle- The main principle of this low-cost solar cabinet dryer is based on greenhouse effect where the solar heat is trapped inside the drying chamber and thus increases the temperature level. It is a mixed-mode solar cabinet dryer. Here both direct and the indirect solar energy collected in the chamber heats up the food products. Collected in the solar collector heats up the fresh air entering from atmosphere through air inlet and is passed through the lowest of the drying chamber and it collects the moisture from the meals product and exhausted thru air outlet. It is completely based totally on herbal phenomenon. No mechanical and the electrical energy are carried out. Here sparkling air having atmospheric temperature enters the dryer at the bottom stop of the sun collector and leaves on the top most part of the drying chamber through exhaust air outlet. The essence of keeping solar energy absorbing portion at an inclination of 23^0 is because, most of the research found that at this angle absorption of solar radiation is maximum [3-7].

(b) Solar Drying System- Food drying is a very simple, ancient skill. It is one of the most accessible and hence the most widespread processing technology. Sun drying of fruits and vegetables is still practiced largely unchanged from ancient times. Traditional sun drying takes place by storing the product under direct sunlight. Sun drying is only possible in areas where, in an average year, the weather allows foods to be dried immediately after harvest. The main advantages of sun drying are low capital and operating costs and the fact that little expertise is required. The main disadvantages of this method are as follows: contamination, theft or damage by birds, rats or insects; slow or intermittent drying and no protection from rain or dew that wets the product, Encourages mould growth and may bring about a notably excessive very last moisture content material; low and variable first-rate of merchandise due to over - or underneath-drying; big areas of land needed for the shallow layers of food; laborious since the crop must be turned, moved if it rains; direct exposure to sunlight reduces the quality (color and vitamin content) of some fruits and vegetables [8-11]. Moreover, since sun drying depends on uncontrolled factors, production of uniform and standard products is not expected. Due to the current trends towards higher cost of fossil fuels and uncertainty regarding future cost and availability, use of solar energy in food processing will probably increase and become more economically feasible in the near future. Solar dryers have some advantages over sun drying when correctly designed. They give faster drying rates by heating the air to 10-30^{0}C above ambient, which causes the air to move faster through the dryer, reduces its humidity and deters insects. The faster drying reduces the risk of spoilage, improves quality of the product and gives a higher throughput, so reducing the drying location this is wanted. However, care is needed whilst drying end result to save you too fast drying, with a view to prevent complete drying and would result in case hardening and subsequent mold boom. Solar dryers additionally protect ingredients form dust, insects, birds and animals. They can be created from domestically available materials at an enormously low capital fee and there are not any fuel costs. Thus, they can be beneficial in areas wherein gas or electricity are highly-priced, land for sun drying is in brief deliver or expensive, sunshine is plentiful but the air humidity is high. Moreover, they may be useful as a means of heating air for artificial dryers to reduce fuel costs solar food drying can be used in most areas but how quickly the food dries is affected by many variables, especially the amount of sunlight and relative humidity. Typical drying times in solar dryers range from 1 to 3 days depending on sun, air movement, humidity and the type of food to be dried [12-15].

III. OBJECTIVES

(a) To reconstruct a modified greenhouse dryer model as per available experimental setup.
(b) To simulate the condition as per available data and predict temperature distribution inside the greenhouse dryer.
(c) To predict relative humidity on different time for moisture removal
(d) To analyze radiation intensity and temperature to determine the moisture content and moisture ratio.
(e) Normal glass is used in modified solar greenhouse dryer for further experiment.

IV. IMPORTANT PARAMETERS

The drying of materials involves migration of water from the interior of the material to its surface, followed by removal of water from the surface, which requires an amount of heat equals to the latent heat of evaporation of water. In most cases, the heat comes from the air, which is heated by the solar air collectors in the case of solar drying. Various important parameters are: -

(a) Determination of Moisture Content - The initial mass (m_i) and the final mass(m_f) of the sample are recorded at an interval of 1 hour till the end of drying using the balance. The moisture content on wet basis (M_{wb}) is given as

$$M_{wb} = \frac{m_i - m_f}{m_i}$$

(b) Determination of Moisture Ratio Moisture ratio is given as

$$MR = \frac{M - M_e}{M_o M_e}$$

where M is the moisture content at any time, M_e is the equilibrium moisture content, and M_o is the initial moisture content of potato flake.

(c) Radiation Formula

$$E_b = \sigma T^4 W/m^2$$

Stefe Boltz Mann's

(d) Relative Humidity

$$Rh = \frac{mv}{mvs}$$

mv = Mass of vapour
mvs = Mass of saturated vapour.

V. EXPERIMENTAL SETUPS

(a) Solar Green House Dryer - Solar drying and natural sun drying experiments are carried out for bitter gourd. Fresh bitter gourd is cut into thin slices, and the initial moisture content is measured by oven-drying method, maintained at a temperature of 105°C for 24 hours by taking 200 g sample. Bitter gourd is then spread uniformly on three trays for solar drying and one tray for natural sun drying. The blower motor is then switched on. The air that is passed through the evacuated tube collector gets heated up and is made to flow into the drying chamber, where bitter gourd is loaded in three trays. During the experiment, ambient temperature, relative humidity and wind velocity, solar insolation, inlet and outlet temperatures of the collector, and temperature of all the trays inside the chamber, temperature of the chimney are recorded at the regular interval of 30 minutes from 10.00 am to 4.00 pm. During the experiment, all the drying trays are weighed on hourly basis until the product acquires constant weight, that is, equilibrium moisture content.

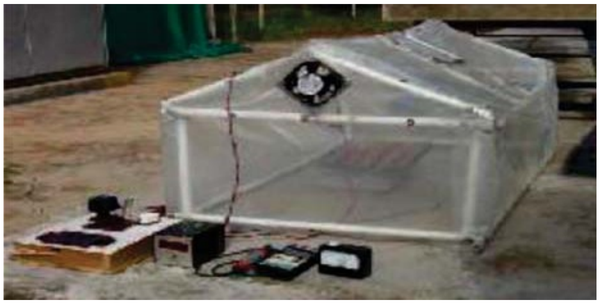

Fig. 1 Experimental setup of solar dryer

Fig. 2 Experimental setup in modified solar greenhouse dryer

(b) Modified Solar Greenhouse Dryer - The proposed greenhouse dryer is of inclined roof even type which is made of rectangular iron pipes and transparent plastic film. The bottom surface of the dryer is packed by black plastic. The roof of the dryer is inclined to latitude of 23˚. The drying tray is made of wire mesh with an effective area of 94 × 58 cm². For flow of air inside the dryer two circular holes of 10 cm diameter are provided below the tray position, and for air outlet rectangular hole is provided on top side of opposite wall. To compare the results of this modified greenhouse dryer one simple greenhouse dryer is also made with same dimensions except the roof inclination. All the parameters were set same as for inclined roof greenhouse dryer. Above Figure shows the instruments used and experimental setup respectively. The drying of potato flakes is performed in open sun drying, simple greenhouse dryer and modified greenhouse dryer under natural convection modes. The experiment is performed between 10 AM to 4 PM. The dryer is kept on the ground and far from shade of the trees and buildings. All the experimental observation is taken at the interval of 30 minutes.

VI. RESULT & DISCUSSION

(a) Experiment Result of Solar Greenhouse Dryer and Modified Greenhouse Dryer Temperature W.R.T. Variation in Time

Table 1: Experimental Results of variation in temperature for the solar greenhouse dryer and modified greenhouse dryer with variation in time.

Time	**Solar greenhouse dryer Temperature (^{0}C)**	**Modified greenhouse dryer Temperature (^{0}C)**
10:00 AM	40	47
10:30 AM	42	48
11:00 AM	39	46
11:30 AM	40	52
12:00 PM	47	57
12:30 PM	46	55
1:00 PM	49	56
1:30 PM	48	53
2:00 PM	48	50
2:30 PM	52	57
3:00 PM	54	58
3:30 PM	53	58
4:00 PM	56	59

Table 1 shows the experimental Results of variation in temperature for the solar greenhouse dryer and modified greenhouse dryer with variation in time. We found that Modified greenhouse dryer are increases the temperature as shown in fig. 3.

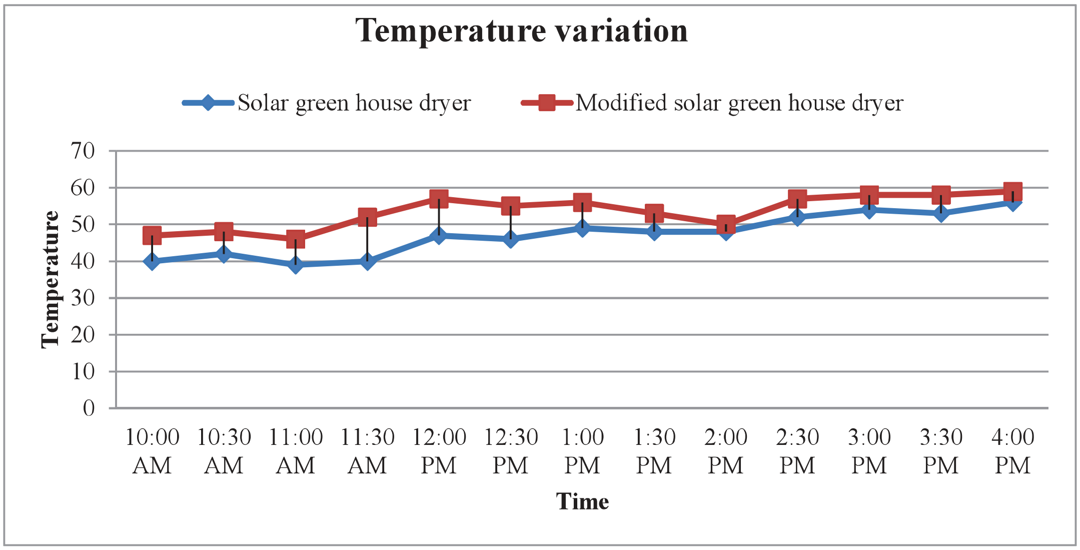

Fig. 3 Experimental Results of variation in temperature for the solar greenhouse dryer and modified greenhouse dryer with variation in time.

(b) Results of Solar Greenhouse Dryer and Modified Greenhouse Dryer Solar Radiation W.R.T. Variation in Time is shown as in Table 2. Experimental solar radiation varied from 964 w/m^{2}to 1141 w/m^2 with maximum value at 2 PM as shown in fig. 4.

Table 2: Experimental Result of variation in radiation for solar greenhouse dryer and modified greenhouse dryer with variation in time

Time	Dryer Solar Radiation (w/m^2)	Modified greenhouse Solar Radiation (w/m^2)	Atmospheric Temperature (^{0}C)	Solar Greenhouse Dryer Fan Velocity Inlet m/s
10:00 AM	964	974	32	3.5
10:30 AM	1100	1050	32	3.5
11:00 AM	1107	1115	33	3.6
11:30 AM	1120	1110	35	3.4
12:00 PM	1140	1148	39	3.2
12:30 PM	1142	1130	36	3.3
1:00 PM	1139	1146	38	3.6
1:30 PM	1138	1148	34	3.2
2:00 PM	1141	1150	35	3.4
2:30 PM	1158	1112	37	3.1
3:00 PM	1094	1102	36	2.7
3:30 PM	1078	1120	33	3.2
4:00 PM	1024	1030	35	3.5

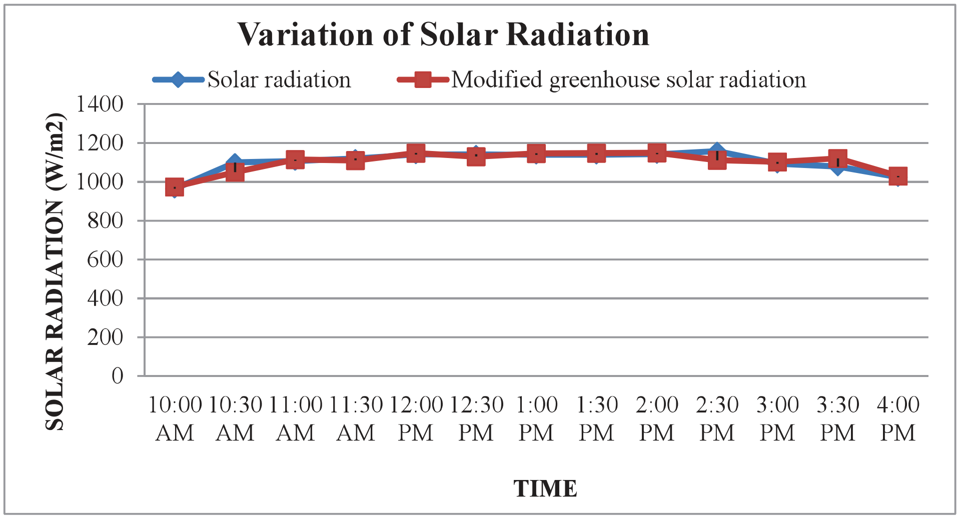

Fig. 4 Experimental Results of solar radiation for the solar greenhouse dryer and modified greenhouse dryer with variation in time.

(c) Results of Solar Greenhouse Dryer and Modified Greenhouse Dryer Relative Humidity W.R.T. Variation in Time

Table 3: Variation of relative humidity

Relative humidity			
Time	**Solar Dryer(^{0}C)**	**Modified greenhouse dryer(^{0}C)**	**Error %**
10:00 AM	30	28	6.6
11:00 AM	24	20	16.66
12:00 PM	23	18	21.73
1:00 PM	20	17	15
2:00 PM	20	18	10
3:00 PM	20	18	10
4:00 PM	15	13	13.33

Table 3 shows the relative humidity values w.r.t time from table, it is determined that relative humidity within the solar greenhouse dryer and modified greenhouse dryer. Modified greenhouse dryer also decreases Relative humidity w.r.t. time. Relative humidity of solar greenhouse dryer under force convection varies between 30% to 15%. If the density of air is low air move upward direction. The same principal is followed here. Due to high temperature in greenhouse dryer and roof inclination the inside humid air moves upper side of inclined roof itself the exhaust fan continuously removes it. The relative humidity inside Modified greenhouse dryer is always less than atmospheric relative humidity.

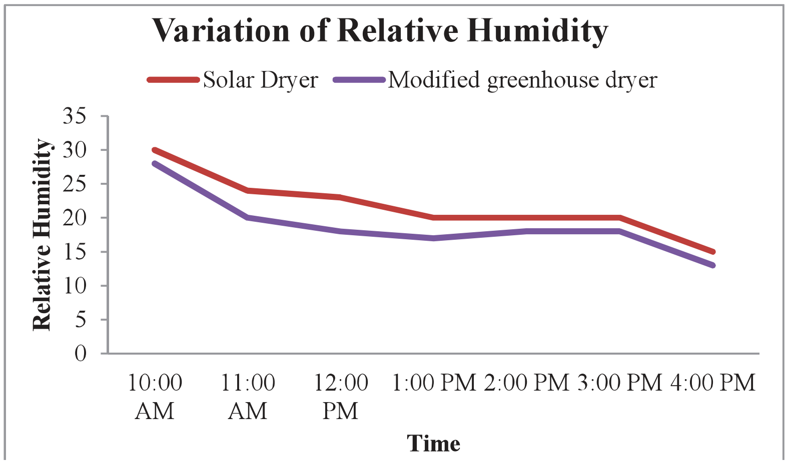

Fig. 5 Variation in relative humidity

(d) Experiment Result of Solar Greenhouse Dryer and Modified Greenhouse Dryer Temperature W.R.T. Variation in Time.

Table 4: Experimental Results of variation in temperature for the solar greenhouse dryer with variation in time.

Time	Solar greenhouse dryer(^{0}C)	Modified greenhouse dryer(^{0}C)	Variation of Results%
10:00 AM	32	36	12.5
11:00 AM	33	38	15.15
12:00 PM	39	43	10.25
1:00 PM	38	42	10.52
2:00 PM	35	40	14.28
3:00 PM	36	39	8.33
4:00 PM	35	37	5.71

Table 4 shows the experimental Results of variation in temperature for the solar greenhouse dryer and modified greenhouse dryer with variation in time. We found that Modified greenhouse dryer are increases the temperature as shown in fig. 6.

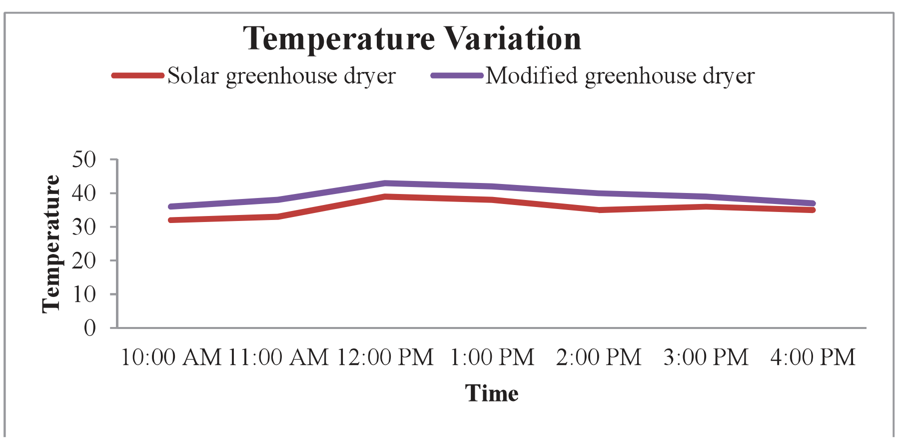

Fig. 6 Variation in temperature for the solar greenhouse dryer with variation in time**.**

(e) Results of Solar Greenhouse Dryer and Modified Greenhouse Dryer Solar Radiation W.R.T. Variation in Time.

Table 5: Experimental results of variation in radiation for the solar greenhouse dryer and modified greenhouse dryer with variation in time

Time	Solar Dryer Solar Radiation (w/m²)	Modified greenhouse dryer Solar Radiation (w/m²)	Atmospheric Temperature (⁰C)	Solar Greenhouse Dryer Fan Velocity Inlet m/s
10 :00 A.M	964	974	32	3.5
11:00 A .M	1107	1115	33	3.6
12:00 P.M	1140	1148	39	3.2
1:00 P.M	1139	1146	38	3.6
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4:00 P.M	1024	1030	35	3.5

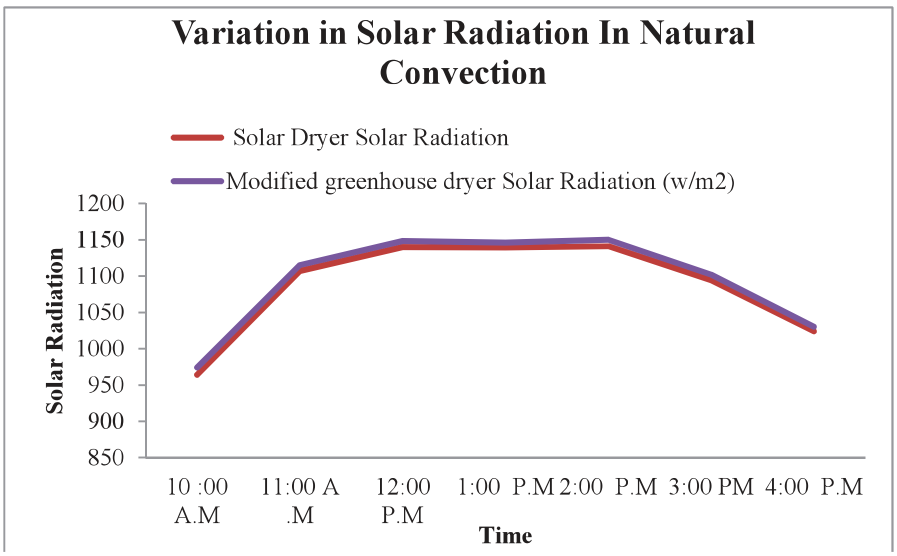

Fig. 7 Variation in experimental results of variation in radiation for the solar greenhouse dryer and Modified greenhouse dryer with variation in time**.**

Figure 7 shows the experimental result of solar greenhouse dryer to determine temperature and Modified greenhouse dryer are slightly above than experimental values.

Comparison of free convection and forced convection

(i) Free convection within a fluid occurs due to density difference within it.

(ii) Force convection occurs due to some external agencies like fan, blower, etc.

(iii) For free convection average value of temperature obtained modified greenhouse dryer varies by about 6.8% to the solar greenhouse dryer for experiment results.

(iv) Variation in solar radiation for frees convection and forced Convection Varies by 0.78% and 0.73% respectively.

VII. CONCLUSION & FUTURE SCOPE

(i) Modified greenhouse dryer experiment results are in good agreement with solar greenhouse dryer experiment results.
(ii) From results, higher value of temperature is found out for Natural convection as compared to forced convection.
(iii) Forced convection shows more convergence than natural convection thus results show improvement of 6.8% average deviation on temperature.
(iv) Effect of solar radiation shows 0.73% average on result thus convergence on solar radiation is achieved.
(v) Thus, experiment of solar greenhouse dryer and modified greenhouse dryer with respect to time shows an optimum result on both natural and free convection at 3 PM.
(vi) Natural convection effect is high thus due to this relative humidity increases and humidity becomes constant thus moisture removal efficiency decreases.

Future Scope

(i) Experimentally analysis can also be done for traditional greenhouse dryer using same Methodology and Boundary condition.
(ii) Inclination angle of greenhouse dryer can be further varied and its effect can be studied on its performance.
(iii) Same methodology can be used to check the performance of indirect type of greenhouse dryers also.
(iv) Tray should be fixed on different angles to increase mass transfer and for better temperature distribution.
(v) Wind velocity of fan could be increased in case of forced convection for a higher amount of moisture removal.

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