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Mathematical Modeling of Solar Tunnel Greenhouse Dryer for Describing the Drying Kinetics of Copra

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Abstract— The most important aspect of drying technology is the mathematical modelling of the drying processes ad equipments. Since moisture ratio and dryer temperature are the deciding parameters for the modelling of a natural convection solar tunnel greenhouse dryer, a mathematical modeling analysis was carried out in the solar tunnel greenhouse drier with biomass backup heater under full load conditions during the month of January 2014. About 5000 coconuts were dried in the dryer from 53.84% initial moisture content to about 7.003% final moisture content for 44 hours and the moisture ratio of the coconuts were calculated for every one hour interval. Ten different modelling were used for determining the theoretical moisture ratio of the coconuts. From the analysis, it was found that the Page method is the best method available for determining the drying characteristics of coconuts since the $_{\chi}2$ and RMSE values are found to be very minimum.

Index Terms—Biomass backup heater, coconuts, drying, mathematical modelling, moisture content, moisture ratio, solar tunnel greenhouse dryer.

I. INTRODUCTION

Drying of fruits and vegetables is one of the oldest methods of food preservation methods known to man. It is the most important process for preserving food since it has a greater effect on the quality of dried products. The major objective in drying agricultural products is the reduction of the moisture content to a level which allows safe storage over an extended period. And also it brings about substantial reduction in weight and volume, minimizing packaging, storage and transportation costs. Drying can be done either by traditional sun drying or industrially through the use of solar dryers or hot air drying. However, large scale production limits the use of open sun drying. Copra is richest source of oil (70%). Moisture content (53.84%, wet basis) in fresh coconuts is required to be reduced to 7% by drying to concentrate oil content. Copra is one of the most economically important fruit crops of India. The conventional method of copra drying is by spreading the split coconuts on open surface for sun-drying.

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This takes 6-8 days for drying and quality deterioration due to deposition of dirt, dust and microbial contamination of wet kernel is unavoidable. The commonly used method of drying agricultural products especially in the developing countries is the direct exposure to sun. Accordingly, 10-30% of such products are lost after harvest before reaching the consumers. Solar dryers could be an alternative to the hot air and open sun drying methods, especially in locations with good sun shine during the harvest season. The use of solar dryers in the drying of agricultural products can significantly reduce or eliminate product wastage, food poisoning and at the sometime enhance productivity of the farmers towards better revenue derived. In solar dryers, the product does not include any kind of preservatives or added chemicals and the product is not exposed to any kind of harmful electromagnetic radiation. Solar drying is a process of using solar energy to heat air and the products so as to achieve dehydration or drying of products. Open sun drying (OSD) has many disadvantages (degradation by wind-blown debris, rain, insect infestation, human and animal interference) resulting in product contamination. Speed of drying and product quality reduces due to over or under drying, intermittent sunshine, wetting by rain etc. 'Solar drying' refers to the method of using the sun's energy for drying, but excludes 'open air sun drying'. The justification for solar dryers is that they may be more effective than sun drying, but have lower operating costs than mechanized dryers. Many researchers have done mathematical modelling studies on the drying characteristics of agricultural products. Reference [1] has done mathematical modelling of thin layer drying process of long green pepper in solar dryer and under open sun and reported that using 13 models, they found that the logarithmic method was found to be most suitable model for describing the drying curve of thin layer forced solar drying process of long green peppers. They also reported that the Midilli and Kucuk model is the best method to describe the drying curve of long green peppers for the open sun mode. Reference [2] has done an experimental validation on thermal modelling of a natural convection greenhouse drying system for jaggery and they reported that the predicted values and experimental observations were in good agreement with each other. Reference [3] has done a mathematical modelling of thin layer drying kinetics of plum in a tunnel dryer and reported that treated plum slices dried faster. They also found that the logarithmic model satisfactorily described the drying behavior of plum slices and also when there is an increase in drying air temperature, then the drying time will decrease.

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Reference [4] has done a thin layer modelling of black tea drying process and reported that in spite of high initial moisture content in black tea particles, the drying of tea particles takes place only on falling rate period. They also reported that an experimental dryer system was designed and operated well and the Lewis model satisfactorily describes the single-layer drying behaviour of black tea particles. Reference [5] has done a modelling of thin layer drying of parsley leaves in a convective dryer and under open sun. They reported that among the nine methods, Verma et.al. model has shown a better fit to the experimental parsley leaves data for open sun drying than other models. The objective of the study is to mathematically model the solar tunnel dryer for determining the drying kinetics of copra. Also, this study reveals the best mathematical model for describing the drying kinetics of copra.

II. EXPERIMENTAL SECTION

Experiments were carried out under meteorological conditions of Pollachi (latitude, 10.39°N; longitude, 77.03°E) in India during month of January 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 with biomass backup heater [4 m (W) x 10 m (L) x 3 m (H) at centre] was designed and constructed at Nallampalli 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.

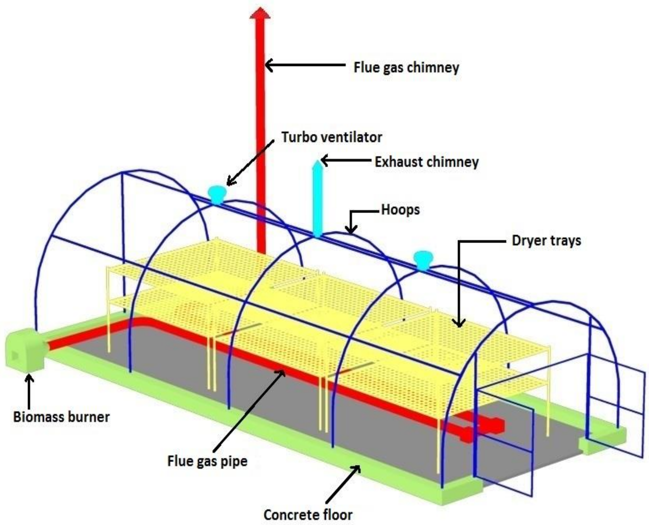

Fig. 1 Solar Tunnel Greenhouse Dryer Coupled with Biomass Backup Heater

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. A biomass heater is coupled with solar tunnel dryer to ensure drying of coconuts even at lower temperatures especially during night time which runs on any type of fuel.

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 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

Experiment was conducted during 22-24th of January, 2014 for the drier placed at Nallampalli village of Pollachi, Tamil Nadu. Matured and good quality coconuts were cut into several pieces. Initial moisture content was calculated by taking 10 different samples from different locations inside the drier. Broken coconuts along with shell were loaded over trays (having 90% porosity) of drier unit. Then, exhaust vents were opened to exhaust initial high humid air. Solar intensity, ambient temperature, dryer temperature, moisture ratio and moisture content 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 had been added as fuel to give heat to solar tunnel dryer. Mass of the fuel added was about 7.5kg/hr.

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VII. DATA ANALYSIS

A. Mathematical Modelling

A mathematical model was developed for predicting the performance of this type of dryer. Before going onto the modelling of solar tunnel dryer, there are some assumptions to be made while developing the mathematical model for the dryer. The assumptions in developing the mathematical model are as follows:

(i) There is no stratification of the air inside the dryer.
(ii) Drying computation is based on a thin layer drying model.
(iii) Specific heat of air, cover and product are constant.
(iv) Absorptive of air is negligible.

B. 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°C for 5 hrs. Initial *(mi)* and final mass *(mf)* 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.

C. Determination of Experimental Moisture Ratio:

Moisture ratio (MR) can be calculated by using the formula,

$$MR = \frac{m_t}{m_i}$$

where,
m_t= moisture content at time 't'
m_i= initial moisture content

D. Determination of Predicted Moisture Ratio:

There are 11 methods available to find out the predicted Moisture Ratio which was selected based on the references [6]-[14]. The methods and formulae used to find out the moisture ratio is shown in the table below:

Table I. Mathematical Models Widely used for Determining the Drying Kinetics of Copra

Model No.	Model Name	Model
1	Newton	MR= exp(-kt)
2	Page	MR= exp(-kt^n)
3	Henderson and Pabis	MR= a exp(-kt)
4	Logarithmic	MR= a exp(-kt) + c
5	Two term	MR= a exp(-k_0t) + b exp(-k_1t)
6	Two term exponential	MR= a exp(-kt) + (1-a)exp(-kat)
7	Wang and Sing	1 + at + bt^2
8	Diffusion approach	a exp(-kt) + (1-a)exp(-kbt)
9	Modified Henderson and Pabis	MR= a exp(-kt) + b exp(-gt) + c exp(-ht)
10	Verma et al	MR= a exp(-kt) + (1-a)exp(-gt)
11	Midilli and Kucuk	MR= a exp(-kt^n) + bt

The table I shows mathematical model widely used for drying kinetics. For mathematical modelling, the thin layer drying equations in table I were tested to select the best model for describing the drying curves of copra during drying process by convective dryer. The reduced (χ^2) as the mean square of deviations between the experimental and calculated values for the models and root mean square analysis (RMSE) was primary criterion for selecting the best equation to describe the drying curve equation and to determine the goodness of the fit. These can be calculated as

$$x^2 = \frac{\sum_{i=1}^{n}\left(MR_{exp.i} - MR_{pre.i}\right)^2}{N-n}$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{n}\left(MR_{pre.i} - MR_{exp.i}\right)^2\right]$$

where, $MR_{exp.i}$ is the ith experimentally observed moisture ratio, $MR_{pre.i}$ is the ith predicted moisture ratio, and N is the number of observations and n is the number of constants.

VIII. RESULTS AND DISCUSSIONS

E. Newton method - Variation of Moisture Ratio with Time:

The fig.2 shows the variation of moisture ratio of the coconuts with time for Newton method during the experimental period. The experimental moisture ratio of the coconuts reduced from 1 to 0.129 whereas the predicted moisture ratio reduced from 0.974 to 0.316.

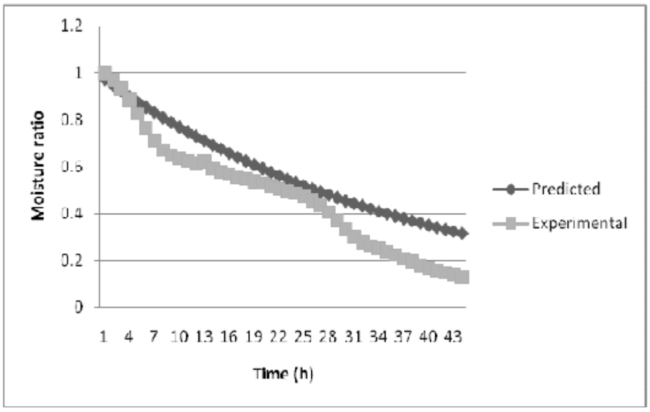

Fig. 2 Variation of Moisture Ratio with Time

F. Page method - Variation of Moisture Ratio with Time:

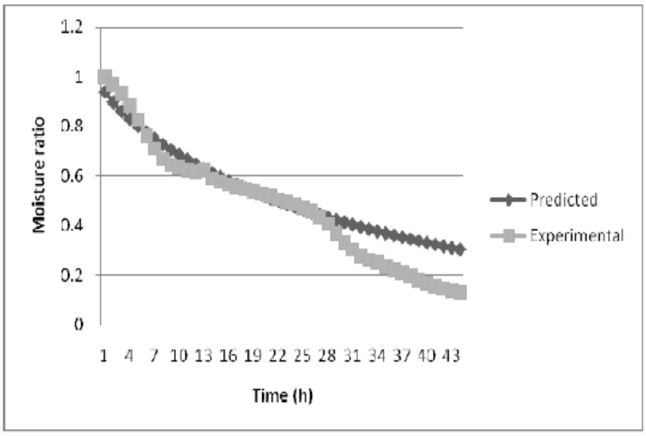

Fig. 3 Variation of Moisture Ratio with Time

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The fig.3 shows the variation of moisture ratio of coconuts with time for Page method during the experimental period. The experimental moisture ratio of the coconuts reduced from 1 to 0.129 whereas the predicted moisture ratio reduced from 0.938 to 0.306.

G. Henderson and Pabis Method - Variation of Moisture Ratio with Time:

The fig.4 shows the variation of moisture ratio of coconuts with time for Henderson and Pabis method during the experimental period. The experimental moisture ratio of the coconuts reduced from 1 to 0.129 whereas the predicted moisture ratio reduced from 0.839 to 0.322.

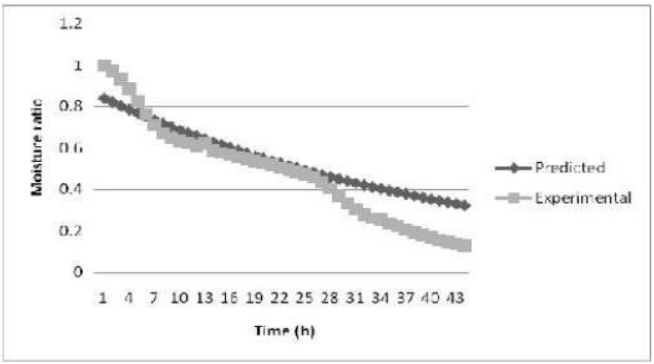

Fig. 4 Variation of Moisture Ratio with Time

H. Logarithmic Method - Variation of Moisture Ratio with Time:

The fig.5 shows the variation of moisture ratio of coconuts with time for Logarithmic method during the experimental period. The experimental moisture ratio of coconuts reduced from 1 to 0.129 whereas the predicted moisture ratio reduced from 1.49 to 1.05.

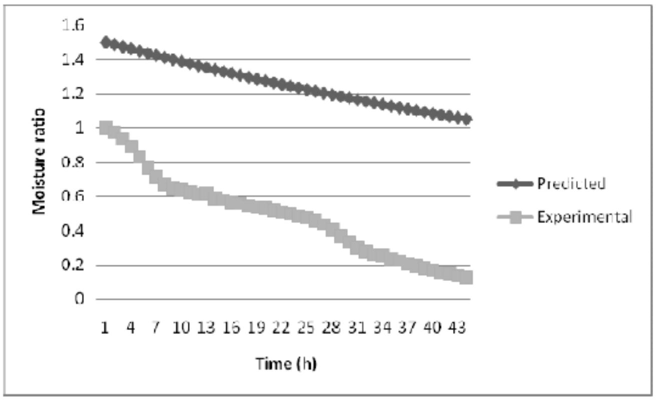

Fig. 5 Variation of Moisture Ratio with Time

I. Two-term method- Variation of moisture ratio with time:

The fig.6 shows the variation of moisture ratio of coconuts with time for Two-term method during the experimental period. The experimental moisture ratio of the coconuts reduced from 1 to 0.129 whereas the predicted moisture ratio reduced from 0.839 to 0.322.

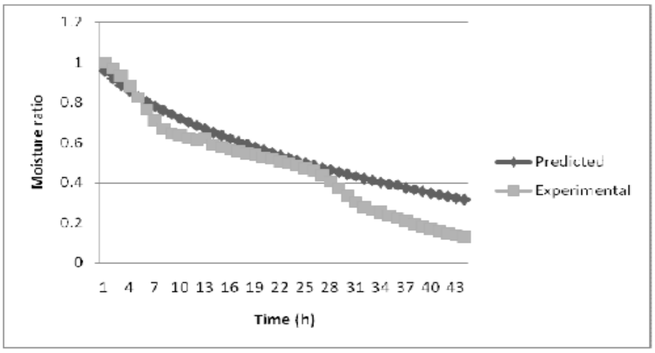

Fig. 6 Variation of Moisture Ratio with Time

J. Two term exponential method- Variation of moisture ratio with time:

The fig.7 shows the variation of moisture ratio of coconuts with time for two term exponential method during the experimental period. The experimental moisture ratio reduced from 1 to 0.129 whereas the predicted moisture ratio reduced from 0.957 to 0.316.

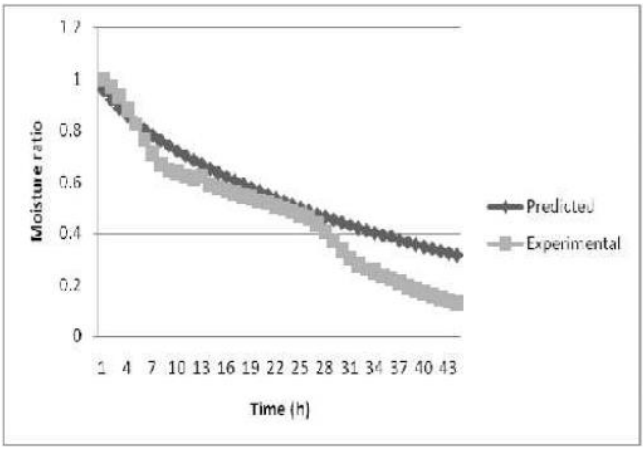

Fig.7 Variation of Moisture Ratio with Time

K. Wang and Sing Method-Variation of Moisture Ratio with Time:

The fig.8 shows the variation of moisture ratio of coconuts with time for Wang and Sing method during the experimental period. The experimental moisture ratio of the coconuts reduced from 1 to 0.129 whereas the predicted moisture ratio reduced from 0.981 to 0.348.

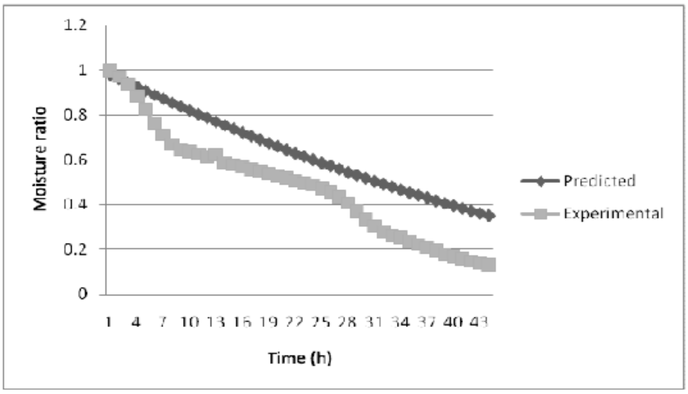

Fig. 8 Variation of Moisture Content with Time

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L. Diffusion Approach Method-Variation of Moisture Ratio with Time:

The fig.9 shows the variation of moisture ratio of coconuts with time for diffusion approach method during the experimental period. The experimental moisture ratio of the coconuts reduced from 1 to 0.129 whereas the predicted moisture ratio reduced from 0.858 to 0.322.

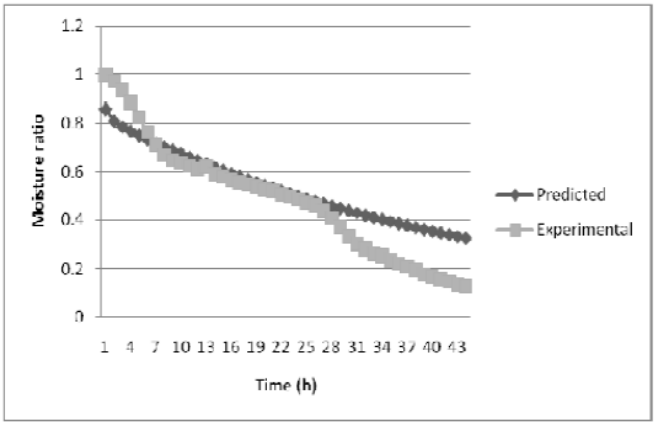

Fig. 9 Variation of Moisture Ratio with Time

M. Modified Henderson and Pabis Method-Variation of Moisture Ratio with Time:

The fig.10 shows the variation of moisture ratio of coconuts with time for Modified Henderson and Pabis method during the experimental period. The experimental moisture ratio of the coconuts reduced from 1 to 0.129 whereas the predicted moisture ratio reduced from 0.839 to 0.322.

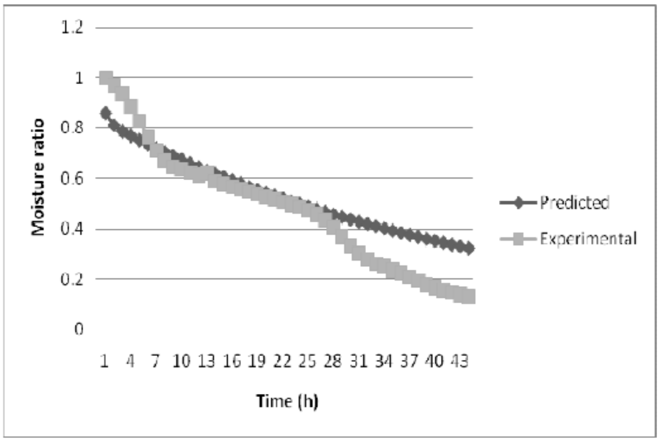

Fig. 10 Variation of Moisture Ratio with Time

N. Verma et al Method-Variation of Moisture Ratio with Time:

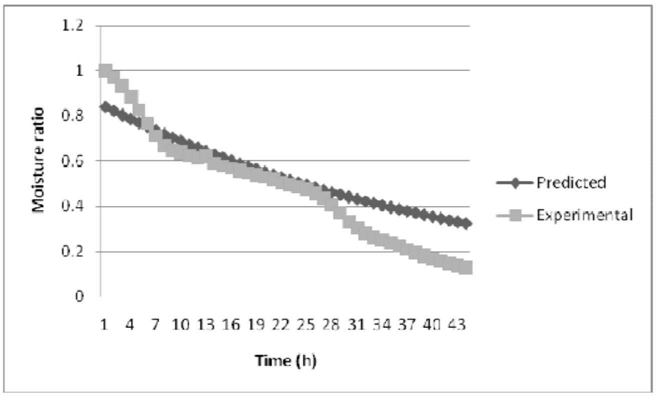

Fig. 11 Variation of Moisture Ratio with Time

The fig.11 shows the variation of moisture ratio of the coconuts with time for Verma et al method. The experimental moisture ratio of the coconuts reduced from 1 to 0.129 whereas the predicted moisture ratio reduced from 0.857 to 0.322.

O. Midilli and Kucuk Method- Variation of Moisture Ratio with Time:

The fig.12 shows the variation of moisture ratio of the coconuts with time for Midilli and Kucuk method. The experimental moisture ratio of the coconuts reduced from 1 to 0.129 whereas the predicted moisture ratio reduced from 0.621 to 0.479.

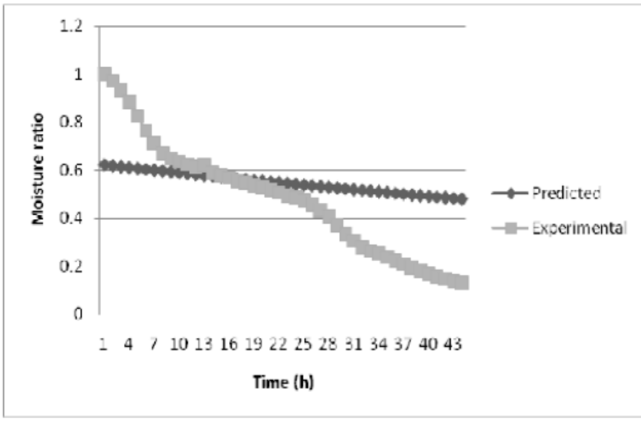

Fig. 12 Variation of Moisture Ratio with Time

P. Variation of Moisture Content with Time:

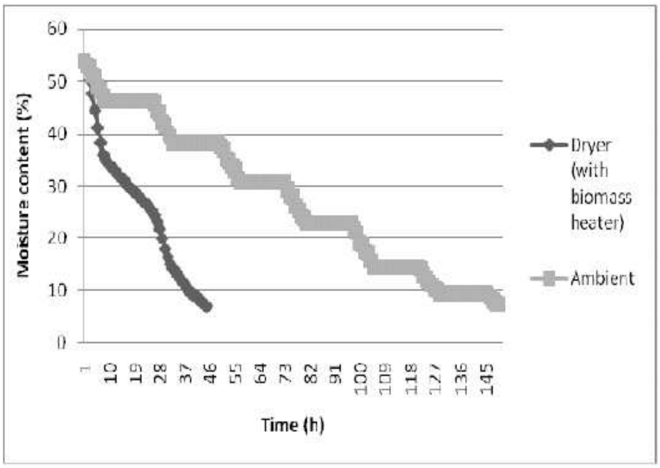

Fig. 13 Variation of Moisture Content with Time

The fig.13 shows the variation of moisture content of coconuts dried inside the dryer (with biomass backup heater) and in the open sun during the experimental period. During the first day, the moisture content of the coconuts inside the dryer reduced from 53.84% to 25.56%. However, for the open sun dried coconuts, moisture content was reduced from 53.84% to 46.32%. By the end of second day, the moisture content of the coconuts inside the dryer reduced from 25.56% to 7.003% which is the optimum level of moisture content for production of oil from coconuts. But for the open sun dried coconuts, moisture content is reduced from 46.32% to 38.46%.

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During the third day, fourth day and fifth day of the experiment, the moisture content of open sun dried coconuts reduced from 38.46% to 30.82%, from 30.82% to 22.98% and from 22.98% to 14.42% respectively. During the sixth day and seventh day of the experiment, the moisture content of the open sun dried coconuts reduced from 14.42% to 9.5% and from 9.5% to 7.4% respectively. By the mid of the seventh day, the moisture content of the open sun dried coconuts was reduced to 7.4% which is the maximum rate of moisture removal from coconuts. In the open sun drying, the products which has an initial moisture content of 53.84%, is reduced to 7.4% for time period of 148 hours, while in the solar tunnel dryer, the products which has an initial moisture content of 53.84%, is reduced to 7.003% for time period of 44 hours which clearly reveals that the coconuts were dried at an earlier time than the open sun drying method. This is due to the effect of biomass backup heater coupled with the solar tunnel greenhouse dryer and also the effect of greenhouse.

IX. Conclusion

The fig.14 shows the drying of coconuts inside the solar tunnel greenhouse dryer coupled with biomass backup heater during the month of January 2014. Experiments were conducted in a natural circulation solar tunnel greenhouse dryer for the mathematical modelling of solar tunnel dryer for describing the drying characteristics of coconuts during the months of January 2014. Three full scale trails with 5000 coconuts were loaded into the solar tunnel greenhouse dryer. The coconuts were dried from 53.84% initial moisture content to about 7.003% final moisture content for 44 hours in the solar dryer.

Fig. 14 Drying of Coconuts inside the Solar Tunnel Greenhouse Dryer

Table II. Mathematical Modelling of Solar Tunnel Dryer

Model No.	Model Constants	Model Name	χ^2	RMSE
1	k= 0.026125	Newton method	0.01501	0.12113
2	**k=0.063688, n=0.772260**	**Page method**	**0.00856**	**0.09044**
3	a=0.858764, k=0.022276	Henderson and Pabis	0.0125	0.10937
4	a= 1.164715, k=0.011395, c=0.347193	Logarithmic	0.6608	0.7847
5	a= 0.4292258, k_o=0.022237, b=0.429228, k=0.022273	Two term	0.01268	0.1073
6	a= 0.091657, k=0.261415	Two term exponential	0.01163	0.1053
7	a= -0.018943, b=0.000094	Wang and Singh	0.0294	0.16576
8	a= 0.163773, k=1.413743, b=0.015338	Diffusion approach	0.0159	0.1217
9	a=0.286233, k=0.022265, b=0.286233, g=0.022265, c=0.286233, h=0.022268	Modified Henderson and Pabis	0.01384	0.10933
10	a= 0.163743, k=1.418512, g=0.021686	Verma et al	0.0125	0.10833
11	a= 2.118203, k=1.220272, n=0.000016, b= -0.006023	Midilli and Kucuk	0.0469	0.20654

Theoretically, the moisture ratio of the coconuts was also calculated in addition to the calculation of experimental moisture ratio. From the analysis, it was found that the Page method is more suitable in describing the drying kinetics of coconuts in the solar tunnel greenhouse dryer coupled with biomass heater since the χ^2 and RMSE values are found to be very minimum (table II) than all the other ten methods available for mathematical modelling of solar tunnel greenhouse dryer. The table II shows the mathematical modelling of moisture ratio according to drying time for thin layer solar drying of copra.

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The table reveals that the Page method is more suitable for describing the drying characteristics of coconuts in the solar tunnel greenhouse dryer since χ^2 and RMSE values are found to be very minimum. From this experiment, it is clear that the Page method was the best mathematical model for describing this drying kinetics of copra in the solar tunnel greenhouse dryer coupled with biomass backup heater.

X. ACKNOWLEDGMENT

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REFERENCES

1. E. Kavak Akpinar and Y. Bicer, Y. "Mathematical modelling of thin layer drying process of long green pepper in solar dryer and under open sun", *Energy Conversion and Management*, 2008, vol.49, pp.1367-1375.
2. Anil Kumar and G. N. Tiwari, "Thermal modelling of a natural convection greenhouse drying system for jaggery: An experimental validation", *Solar Energy*, 2006, vol. 80, pp.1135-1144.
3. R. K. Goyal, A. R. P. Kingsly, M. R. Manikantan and S. M. Ilyas "Mathematical modelling of thin layer drying kinetics of plum in a tunnel dryer", *Journal of Food Engineering*, 2007, vol.79, pp.176-180.
4. P. C. Panchariya, D. Popovic, and A. L. Sharma, "Thin layer modelling of black tea drying process", *Journal of Food Engineering*, 2002, vol.52, pp.349-357.
5. E. KavakAkpinar, Y. Bicer, and F. Cetinkaya, "Modelling of thin layer drying of parsley leaves in a convective dryer and under open sun", *Journal of Food Engineering*, 2006, vol.75, pp.308-315.
6. K. Sacilik, "Effect of drying methods on thin-layer drying characteristics of hull-less seed pumpkin (*Cucurbita pepo* L.)", *Journal of Food Engineering*, 2007, vol. 79 (1), pp. 23-30.
7. I. T. Togrul and D. Pehlivan, "Modelling of thin layer drying kinetics of some fruits under open-air sun drying process", *Journal of Food Engineering*, 2004, vol. 65, pp. 413-425.
8. A. Midilli, H. Kucuk and Z. Yapar, "A new model for single layer drying", *Drying Technology*, 2002, vol. 20 (7), pp. 1503-1513.
9. O. Yaldiz, C. Ertekin & H. I. Uzun, "Mathematical modelling of thin layer solar drying of sultana grapes", *Energy*, 2001, vol. 26, pp. 457-465.
10. I. Doymaz, "Sun drying of figs: an experimental study", *Journal of Food Engineering*, 2005, vol. 71 (4), pp. 403-407.
11. E. K. Akpinar, Y. Bicer and A. Midilli, "Modeling and experimental study on drying of apple slices in a convective cyclone dryer", *Journal of Food Process Engineering*, 2003, vol. 26(6), pp. 515-541.
12. H. O. Menges and C. Ertekin, "Thin layer drying model for treated and untreated stanley plums", *Energy Conversion and Management*, 2006, vol. 47 (15-16), pp. 2337-2348.
13. T. Günhan, V. Demir, E. Hancioglu and A. Hepbasli, "Mathematical modelling of drying of bay Leaves", *Energy Conversion and Management*, 2005, vol. 46 (11-12), pp. 1667-1679.
14. A. Midilli and H. Kucuk, "Mathematical modelling of thin layer drying of pistachio by using solar energy", *Energy Conversion and Management*, 2003, vol. 44, pp. 1111-1122.
15. P. S. Madamba, R. H. Driscoll, & K. A, Buckle, "The thin layer drying characteristics of garlic slices", *Journal of Food Engineering*, 1996, vol. 29, pp. 75-97.
16. K. Sacilik, R. Keskin, & A. K. Elicin, "Mathematical modeling of solar tunnel drying of thin layer organic tomato", *Journal of Food Engineering*, 2005.
17. A. Gungor & N. Ozbalta, " Design of a greenhouse for solar drying of sultana grapes and experimental investigation on it", International Conference on Thermal Engineering and Thermogrammetry (THERMO), 18-20 June 2003, Budapest, Hungary.
18. A. Kaya, O. Aydin, C. Demirtas, & M. Akgun, "An experimental study on the drying kinetics of quince", *Desalination*, 2007a, vol. 212, pp. 328–343.
19. A. Kaya, O. Aydin, C. Demirtas, "Drying kinetics of red delicious apple", *Biosystems Engineering*, 2007b, vol. 96, 517-524.
20. U. S. Pal & A. Chakraverty, "Thin layer convection drying of Mushrooms". *Energy Conversion and Management*, 1997, vol. 38(2), pp. 107-113,
21. P. N. Sarsavadia, R. L. Sawhney, D. R. Pangavhane & S. P. Singh, "Drying behaviour of brined onion slices", *Journal of Food Engineering*, 1999, vol. 40, pp. 219-226.
22. C. Ertekin & O. Yaldiz, "Drying of eggplant and selection of a suitable thin layer drying model", *Journal of Food Engineering*, 2004, vol. 63 (4), pp. 349-359.

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Publications *(number only)*

Books	Research Papers/ Reports	General Articles	Patents	Others (Please specify)
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Publications ***(number only)***

Chapters in Books	Research Papers/ Reports	General Articles	Patents	Others (Please specify)
04	36	163	----------	------------

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