iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** XII **Month of publication:** December 2018

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue XII, Dec 2018- Available at www.ijraset.com

Effect on Beetroot Samples in a Solar Conduction Dryer

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Abstract: A flat plate type natural convective solar dryer is designed and constructed for conducting thin layer drying experiments of beetroot samples. Determination of the air-drying characteristics of beetroot by thin layer solar drying process is carried out by subjecting it to various combinations of heat transfer like Conduction, Convection and Radiation along with simulation of thin layer solar drying process of beetroot done by Newton (Lewis) thin layer drying model. The drying process of beetroot was carried out during daylight time of around 8 hours. The dramatic moisture reduction of beetroot took place during the peak hours of solar intensity from 11:00 am to 15:00 pm. Beetroot samples were dried from a decimal initial moisture content of about 87% w.b to a decimal final moisture content of about 7% w.b. The drying process occurs in falling rate period and moisture diffusion was the dominant physical mechanism governing moisture movement within the beetroot samples.

I. INTRODUCTION

Drying is a very effective method which protects food and inhibits growth of bacteria and yeasts by removal of water [1,2]. Electrical heaters need over 3 kW of primary energy for supplying 1 kW of evaporation [3]. In the present scenario, researcher and engineers focus on to design and manufacture efficient systems or devices in order to harness renewable energy for drying products.

Drying reduces the water activity of the produce to a level below which deterioration does not occur for a definite duration [4,7]. High prices and shortage of fossil fuels have increased emphasis on using alternative renewable energy resources and hence drying is preferred because of the same. [8].

Solar drying is an elaboration of the sun drying process and an efficient system of utilizing solar energy [8,9 10-12]. The taproot portion of the beet plant is the beetroot. Other than as a food, Beets have use as a food coloring and as a medicinal plant. Beets also contain the B vitamin folate, which helps reduce the risk of birth defects. Considering so many benefits and importance of beetroot, we have selected this vegetable for drying purpose. If beetroot can be dried and hence preserved for longer time can yield benefits for humanity for a longer duration.

II. RELATED WORK

The popularity of products which are dried have longer shelf life, substantial volume reduction and product diversity. Applications of dryers in the countries which are developing can reduce the losses postharvest and contribute significantly to the availability of food in these countries [23].

Solar dryers need to be properly designed in order to meet specific drying requirements of agricultural products and give satisfactory performance for energy requirements like dimensions, airflow rate ,temperature, relative humidity, the characteristics of products, system configurations and drying seasons.

The prediction of drying rate of the specific crops under different conditions is very important for the design of the drying systems. Full-scale experimentation for various products and systems configurations is sometimes costly and not possible. The valuable tool for prediction of performance of solar drying systems is the use of a simulation model.

Many investigators have carried out mathematical modeling and experimental studies on the thin layer drying of various fruits and vegetables. For example, potato slices, okra, coroba slices, sweet cherry, mango slices, carrots, pistachios [2, 16].

Therefore, the present study was aimed with the following main
objectives:- To observe process of drying of beetroot in cylindrical slices while drying in a solar conduction dryer (SCD) in typical low humidity and comparatively medium solar intensity situation of Mumbai (India) and to study changes in multiple parameters of beetroots on being selectively exposed to conduction, convection and radiation compared to when exposed to all the modes to understand the contribution from these different modes of heat transfer.

III. PLAN OF EXPERIMENTS

A. Moisture Ratio

Drying of the samples was observed to be in falling rate mechanism i.e., with the time moving forward the drying rate decreases. The moisture diffusion of rhizomes can be generalized for moisture ratio (MR) [1] expression, which is given as:

$$MR = \frac{M - M_e}{M_0 - M_e}$$

Where M is the material moisture content in % at time t, M_e is the equilibrium moisture content % of the material, M_0 is the initial moisture content of the material % .All the Moisture content are calculated on Wet Basis (wb)

MR could also be written as [1]

$MR = A \times e^{-kt}$ Where the constants are: $A = \frac{8}{\pi^2}$ for slab, $A = \frac{6}{\pi^2}$ for cylinder, $k = \frac{\pi^2 \times D_{eff}}{4 \times h^2}$

Simplifying it into linear form: $lnMR = ln\frac{M-M_e}{M_0-M_e} = \ln(A - kt)$

The effective moisture diffusivity of samples can be calculated [1] $k = \frac{\pi^2 \times D_{eff}}{4 \times h^2}$

B. Machine Learning

We have used the Machine learning technique here to create the graphs using python which is a machine learning technique and which helps eliminate minor discrepancies in the data like difference in the starting point of the graphs. This gives a proper end to end graphs concatenates different readings in one graph.

C. Drying Equipment

The Solar conduction dryer is a solar powered food dehydrator (Fig. 1) developed by a group of innovators known as Science for Society (S4S). The device utilizes solar power in a conductive manner as well as convective way for drying. The structure of solar conductive dryer which comprises of four drying chambers constructed from hollow sections of stainless steel. The dryer has four drying trays, covering a surface area of 1.04 m^2 each. Transparent plastic (PC Multiwall Sheet) is used to cover the trays. The trays are coated with black color special food grade coating, where the products to be dried are placed.

Fig 1 Solar conduction dryer

D. Experiment Procedure

These experiments were performed in the month of April, 2016. It was carried out during the daytime ranging from 10:00 am to 19:00 pm for approximately 7-8 hrs. The initial moisture content has maximum value of 87% to minimum 83% to final moisture content of minimum 7% to 15%.Four samples from the same beetroot were sliced. Four parameters of the beetroot were recorded at the start of the experiment and after some interval of time which included the diameter, moisture content, weight and thickness. Vernier calipers were used to measure the diameter and the thickness. A PCE instrument moisture analyzer was used to find out the initial and final moisture content. Infrared temperature sensor was used to measure temperature on the surface of the beetroot sample and on the surface of the tray of the SCD. A lab weighing machine was used to weigh the samples.

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1) *Condition 1*
a) *Conduction+ Convection:* A small bridge made up of wood of height 10 cm, width 10 cm and width 2 cm was kept above 3 samples while the fourth sample was kept on the top of the dryer surface only which was subjected to all the three modes of transport i.e,. conduction, convection and radiation
2) *Condition 2*
a) *Radiation+ Convection:* 3 samples were kept on a small bridge made up of wood of height 10 cm, width 10 cm and width 2 cm while the fourth sample was kept on the top of the dryer surface only which was subjected to all the three modes of transport i.e,. conduction, convection and radiation on the dryer surface only.

E. *Readings and Measurement*

The readings taken using the aforesaid methods and instruments were recorded in a tabular form after different intervals of time. From this collected data, four parameters were considered for the experimental study and modeling the data which were Moisture content by percentage from the moisture analyzer machine , Diameter of sample, Thickness of sample ,Weight of the sample. Also the percentage change in these samples were also recorded for comparison. Based on this data, Modeling was done using Newton Lewis model.

IV. OBSERVATION

A. *Experimental Observation*

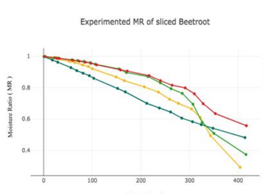
MR Formula used for our study was Lewis Model. Following are the formulae for Lewis Model.

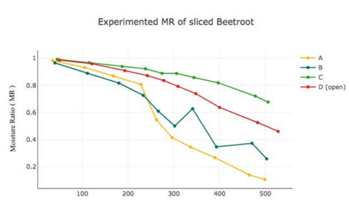
1) *Formula:* $MR = e^{-kt}$ $k = \frac{\pi^2 \times D_{eff}}{4\times h^2}$ *where, t= minutes passed, h= thickness, k= Moisture Rate const*

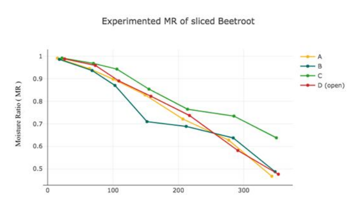
D_{eff} = *effective moisture diffusivity* = 3.01×10^{-9} m^2/s

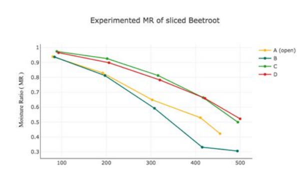
The experiment was done two times for each type of heat transfer for variable size samples from a same sliced beetroot to study the change in Moisture Ratio (MR) and Moisture Content. Following are the graphs for the different experiments.

a) *Exp1:* Conduction+Convection Exp2:Conduction+Convection
b) *Exp3:* Radiation+Convection
c) *Exp4:* Radiation+Convection









B. *Experiment Inferences and Observation*

Figures 3 and 4 show the drying curves i.e. change in moisture ratio against time for conduction and convection. The moisture ratio is plotted along the Y axis and time along X axis.The time for which the data of the sample is recorded and the corresponding results are calculated is 8 hours. It is observed that after an initial slowness, the rate of drying increases rapidly. In Figs 3 and 4, on an average, close to 20% reduction takes place in the first 180 minutes i.e the moisture ratio falls to 0.8 (wet basis). This rate of drying is much faster due to the fact that exposure of sunlight to more porous surface initially leads to a faster reduction in moisture. However post 180 minutes the drying process slows down for the next 120 minutes post which it again picks up rapidly. This late surge of reduction of moisture content is also due to the fact that the material involved has undergone considerable amount of drying Post 400 minutes it is also observed that the Moisture Ratio is often more than 60% percent and hence the study is not undertaken any further as the material sample also has been sufficiently degraded. In Figures 5 and 6 the drying curve i.e change in moisture ratio against time for radiation and convection is plotted. From the graphs we can infer that the rate of change of Moisture Ratio (MR) is higher in most of the cases whereas it is almost the same in other few cases. From the tables of thickness, we discuss the study from experiment 4, when the thickness was 3.07 in a sample the % change in that was 35.50% whereas when it was 4.99 the percentage change was 53.9%. Thus we can conclude that if thickness is high then the rate of change of thickness is also higher and if thickness is less than the rate of change of thickness is lower. Also when the thickness was less than 3mm the rate of change of thickness was lesser than 20%. In addition to the above it is observed that, the rate of change of thickness is higher in radiation +

convection case than in the case of conduction + convection. From Experiment 2, the rate of change of moisture content tends to be lower if the weight of the initial sample is higher. In this case when the weight was 12.1 g the % change, in moisture content was 87.51% whereas in the Sample A, whose weight was 6.8g the percentage change in moisture content is 89.51%. .Also the percentage weight loss by the sample is more in case of lower weight sample as compared to a higher weight sample..

As far as the experimental study indicates, during either conduction, convection or radiation, there has been no significant trend in the change in diameter of the samples.

V. CONCLUSION

From the above study it can be concluded that the rate of change of moisture ratio is higher if we transfer the heat to any given sample using radiation and convection. Also it was observed that the samples tend to lose more heat when they have a higher thickness ratio. The final change in diameter of the sample content tends to be almost double of change in moisture and weight of the sample. It seems from the above experiments that radiation and convection turned out to be superior heat transfer method for drying out cylindrical sliced samples of beetroot.

This may not hold true for fully uncut samples of beetroot as we have seen that rate of change of Moisture ratio tends to be generally faster if the thickness of the given sample is higher. The maximum change of Moisture ratio (MR) was 90% for radiation and convection while it was 89% for conduction and convection. The decline in rate of drying in beginning phase has a tendency to be more extreme and articulate when contrasted with later stages of drying.

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue XII, Dec 2018- Available at www.ijraset.com

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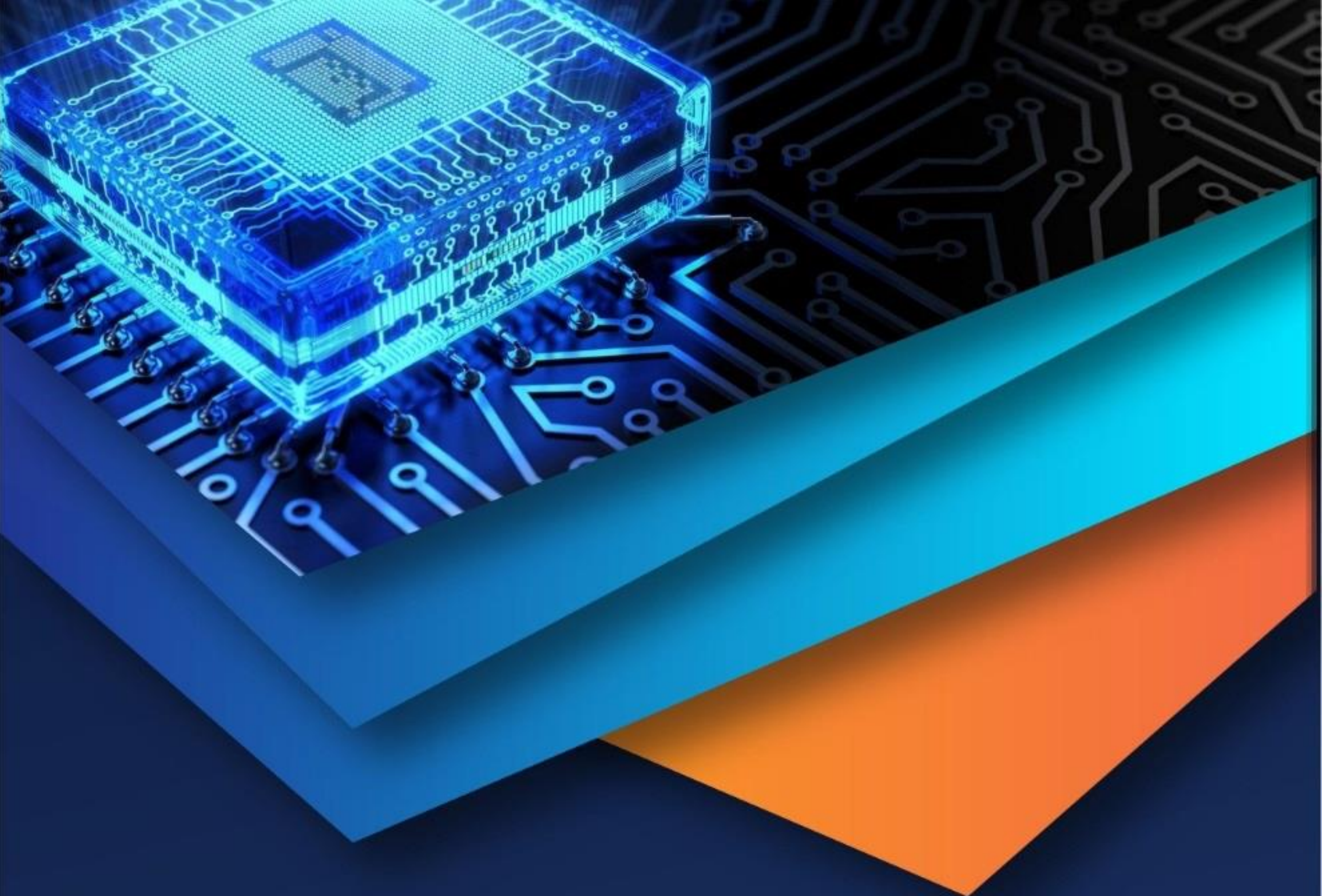

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