THERMAL KINETICS OF THIN LAYER DRYING OF INDIAN GOOSEBERRY OR ANOLA FLAKS (PHYLLANTHUS EMBLICA)

Dinesh Kumar¹, Dr. L.P. Singh², Dr. Anil Kumar Singh³

¹Research Scholar, Dept. of Mechanical Engg. SHIATS-DU, Allahabad
²Assistant Professor, MED, SHIAT-DU, Allahabad
³Associate Professor, Dept. of Mechanical Engg. and Principal (I/C), Lok Nayak Jai Prakash Institute of Technology Chapra- 841302 (Bihar), India

ABSTRACT

The aonla (Phyllanthus emblica), a fruit rich in vitamin-C, has high medicinal importance in human life. Drying of aonla in the form of flakes and powder is one of the widely used methods of its preservation. Thermal kinetics during drying a hygroscopic material in thin layer, the moisture ratio is calculated by the Half Life Time Method. The experiment was conducted at an average velocity of 0.48 m/s, relative humidity 35% and temperature in the range from 40 to 75°C. Comparing the experimental values with the predicted values using Newton’s Model, Page Model, Modified Page Model on the basis of Root Mean Square Error (RMSE), chi-square (χ²) and Efficiency (EF), RMSE and χ² were found lowest and EF .RMSE lay between 0.0382 and 0.0094, reduced χ² between 0.000132 and 0.00761 and EF between 0.9598 and 0.9985. Thus, this thermal kinetic model can be used to predict the moisture of the aonla at any drying instant during thin layer drying process with reasonable accuracy.

Keywords: Aonla (Phyllanthus Emblica), Drying, Drying Kinetics, Hygroscopic Material, Half Life Time Method, Indian Gooseberry.

1. INTRODUCTION

Drying, one of the most energy-intensive and thermal processes is used for storage and processing of cereal grains in chemical and food industries. Whereas dehydration is the removal of moisture to a very low moisture content, nearly a dry-bone condition [16], the basic objective of drying a food fruit is the removal of moisture to a level, which would prevent the growth of moulds and insects that normally cause spoilage [6], yet retaining the germination capacity.
A large amount of energy is consumed in a drying process every year all over the world. Therefore understanding the thermal kinetics during drying process is necessary in establishing design requirements for an energy-efficient drying system. Drying may be accomplished by adsorption, mechanical separation, vaporization, chemical means or a combination of two or more of the above methods. In this paper, only artificial drying of hygroscopic fruits using heated air as a drying medium will be considered.

When a hygroscopic material is exposed to a particular environment for a long time, the grain adsors or desorbs moisture depending on whether its vapour pressure is less or greater than that of the environment. The flow ceases when the two vapour pressures become equal and the grain is said to have reached equilibrium moisture content (EMC), the EMC depends on the variety and maturity of the grain and the humidity and temperature conditions of the environment. Since determination of EMC, \( \text{EMC} \) requires separate experiment for the material under consideration, a few researchers have suggested use of another simpler definition of moisture ratio \( MR = \frac{M}{M_0} \) in place of \( \frac{M - \text{EMC}}{M_0 - \text{EMC}} \). Lewis proposed a model analogous to Newton’s Law of cooling.

\[
\frac{dM}{dt} = -k(M - M_e) \tag{1.1}
\]

The thin layer drying experiment was conducted with air of given humidity and temperature. Moisture content, \( M \) during drying, was taken on dry basis. The moisture ratio \( M/M_0 \) was calculated from the moisture content (% d.b.). The thermal kinetics during drying the relationship between moisture ratios and drying instants was determined. Based on the Lewis proposal, seven models were proposed by researchers.

2. EXPERIMENTAL SET-UP AND PROCEDURE

The experimental set up consist of three main units: Humidification chamber, Air heating system, and drying unit. The humidification chamber was constructed of galvanized iron sheet in two cylindrical parts, which were joined together by means of an airtight flange-joint. The lower part of the humidification chamber is of 0.3 m diameter and 1 m height. A float valve is employed in order to maintain a desired level of water in the lower portion of the chamber. An overhead water tank supplies water to the chamber. The air suction pipe, 3 m long and 106 mm in diameter, is connected to the humidification chamber through an orifice meter just above the water level. The lower part of the humidification chamber is also provided with a water level indicator, a drain valve, two 2-kW electric immersion heaters, a water pump and a 12 mm diameter perforated spray tube.

![Thin Layer Drying Unit](image)
2.1 Preparation of the fruit samples

A batch of 50 kg of Aonla fruits was obtained from aonla tree. The fruit was cleaned, sorted and graded before it was used for the experiment. The fruit samples at the desired moisture were obtained by adding calculated amounts of distilled water to the fruit and then sealed in separate bags. The samples were kept at 278 K in a refrigerator for a week to enable the moisture to become uniformly distributed throughout the material. Before starting a test, the required quantity of the fruit was taken out of the refrigerator and was allowed to warm up to the room temperature. The initial moisture contents and the equilibrium moisture content and time taken for this change are recorded and the values of M/M₀ from experimental observation are calculated.

2.2 Thin-layer drying

To obtain thermal kinetics during drying the desired values of velocity, temperature and relative humidity of the drying air, airflow rate and energy supplied to the water-heater and air heaters were suitably adjusted. It was ensured that the system achieved steady state conditions; it was only after about one hour that the drying experiments could be started. About 1 kg of Aonla flakes was weighed and distributed uniformly in a thin-layer, one flake high, in each of the drying pans. The drying pans were then placed on the openings in the base plate in the exposure chamber. As the drying continued, the samples were weighed periodically. The duration between two consecutive weighing was 6 min during the first hour and 12 min thereafter. As the drying proceeded, the drying rate decreased. The time interval beyond 12 h of drying was increased to 30 min. The drying was continued until the weight difference between two consecutive readings of a drying sample was negligible. The experimental observations were obtained for the following conditions: Initial moisture content was about 35%, Average air velocity of drying air 0.48 m/s, Drying air temperature: 323, 333, 338, 343, 348, 353 & 358 K with two dew-point temperatures (approximately 293 and 303 K).

3. METHOD OF SOLUTION

To determine the thermal kinetics of drying thin layer, an Analytical determination of drying coefficient “k” by Half Life Method.

The drying equations used by researchers [11, 21] were of the following type

\[
MR = \frac{M - M_o}{M_o - M_i} = Ae^{-kt}
\]

(3.1)

By plotting the value of natural log of experimental MR against drying time for a given drying air temperature, they found the plot to be a straight line, the slopes gives the drying coefficient and the intercept the natural logarithmic value of the shape factor for the temperature under consideration. It is assumed that the types of equation remain the same when the definition of Moisture Ratio is changed to MR=M/M₀ and therefore, MR becomes

\[
MR=M/M_0 = A e^{-kt}
\]

(3.2)
The value of “k” can be determined analytically by the half-life Method. Half-life period is the time of one-half response in a drying process and can be defined as the number of hours necessary to obtain a moisture ratio of one-half. Using the experimental results on drying of Aonla obtained in the present work, with drying air at 50°C, drying time at which MR is half, (i.e. \( \frac{1}{2} \)) can be found by linear interpolation at 4 and 8 hours.

Using the values of drying coefficient k and shape factor A for various drying temperatures, the correlation are found as given below:

\[
k = 0.0267e^{0.0243T} \quad \text{and} \quad A = 2.4095T^{-0.2325}
\]
thus the drying equation

\[ MR = \left( \frac{M}{M_o} \right) = (2.4095 \ T^{-0.2325} \ exp - (0.0267 \ e^{0.0243 \ T}) \ t \]

Where \( t \) is the drying time in hours, and \( T \) is the drying air temperature in \(^\circ\)C.

4. MODELS FOR THE DRYING OF AONLA FLAKES

There are No of Mathematical models as Newton Model; \( MR = \exp(-kt) \), Page Model; \( MR=\exp(-kt^n) \), Modified Page Model; \( MR = \exp [(-kt)^n] \) etc. From Page Model; \( MR=\exp (-kt^n) \), the values of \( \chi^2 \), RMSE and EF for various values of empirical constant (n) at a given drying air temperature 50\(^\circ\)C, it was found that the value n=1 has maximum EF (efficiency) and minimum RMSE value shown in Curve fitting criteria for semi-theoretical thin layer drying model for the drying of aonla.

4.1 Summary

For values of RMSE and EF (Efficiency) Page Model & Modified Page Model are equal from 50 to 75\(^\circ\)C (higher temperature) where as the value of \( \chi^2 \) is different for air temperatures above 65\(^\circ\)C onwards. RMSE values for Page Model varies from 0.0067 to 0.0766.
5. CONCLUSIONS

For modeling and numerical approach of thermal kinetics during drying the hygroscopic material, the experimental moisture content data were used on the dry weight basis.

The drying models, namely Newton’s Model, Page Model, and Modified Page Model etc. were compared on the basis of their statistical coefficients such as Root Mean Square Error RMSE, chi-square and Efficiency EF to see how close the predicted values were to experimental one.

7. REFERENCES