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A Review on Drying Characteristics and Mathematical modeling of drying of *Camellia sinensis*

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Abstract: Drying is required for the food preservation and is widely used worldwide. Numerous drying techniques and methods are used in drying of different agricultural products. Each technique has its own advantage and limitation. Drying process makes the food lighter in weight which is easy to transport, requires smaller space for storage and gives it the longer life. Present study involves the evaluation of the drying characteristics and mathematical modelling of *Camellia sinensis*, under different drying temperatures. The performance of the best model does depends on the determination and comparison of the correlation coefficient (R), mean bias error (MBE), root mean square error (RMSE), and reduced chi-square (χ^2).

Keywords: Drying Characteristics, mathematical modelling, *Camellia sinensis*,

INTRODUCTION

The demand of the dried food products all over the world is increasing permanently (Hamrouni - Sellami et al., 2012). While processing the medicinal plants one of the important operations is drying that involves the removal of moisture from the plant product, and preserve from getting rotten due to the presence of moisture, protection from flies, rain, dust and pest (Anupamtiwari et al., 2016). In the competitive market food, pharmaceuticals, perfumes, cosmetics medical plants are used vastly.

Cymbopogon citratus commonly known as lemon grass and It is commonly designated by this name because is presents a characteristic flavour of lemon (Vivekkumar et al., 2014). Aqueous leaf extract of lemon grass have anti-oxidant role on paracetamol. The lemongrass has a huge demand in the nutritional, medical, and flavouring industry. It has to be dried first before storing, as storing it fresh for a long period in the ambient condition results in the rotten leaves (Nwosu, et al., 2015).

The effect of different drying parameters viz. temperature, humidity and air velocity on phenolic contents of *Azadirachta indica*, color measurements of *Camellia sinensis*, and essential oil obtained from *Cymbopogon citratus* are depicted (Anupamtiwari et al., 2016).

Thin layer modeling and drying characteristics of tea had been investigated from temperature range 80 to 120°C and the range of air velocity of 0.25 to 0.65 m/s and Lewis model was proposed for the thin layer drying characteristics for the same as compared to other models (Panchariya et al., 2002).

An experiment was performed in modified greenhouse dryer at an air temperature of 50°C for drying herbal tea. The Wang and Singh model was found to be most satisfactory and the values obtained with highest value of R^2 (0.9993) and least value of MBE (-0.0007-0.00412). The effective moisture diffusivity increased with temperature and varied from 9.28×10-11 to 2.606×10-10 m2/s and the activation energy value was found to be (24.91 kJ/mol) (Sarobo et al., 2018).

Thin layer drying characteristics of freshly plucked leavs was studied to know about the moisture transfer of leaves within a temperature range of 20°C – 35 °C and humidity range of 40%-90% and airflow rate of 1.2 ± 0.3 m/s. It was found that two term model predicted the best moisture transfer than others. Effective diffusivity of water was observed to vary from 3.3409 – 5.4669 × 10–10 m^2/s and the activation energy was 1477.75 kJ/kg (Botheju et al., 2010).

In tea processing withering is the preliminary stage where it undergoes physical and chemical transformation for next phase. The withering process at controlled temperature conditions and relative humidity reduces moisture content of tea leaves from actual value of 74%-83% to 66%.

Solar drying (single layer) was conducted on Mexican tea leaves on different temperatures of ambient air and drying air temperature. The ambient air temperature was taken as 21 to 30 °C, drying air temperature 45 to 60 °C with relative humidity 29 to 53 %, airflow rate 0.0277 to 0.0556 meter cube per second and solar radiation 150 to 920 W/m^2. 14 different methods were used to obtain experimental data and compare them according to statistical parameters. The Wang and Singh model was found to adequately describe the drying curves with lowest MBE ($4x10^{-5}$), highest (r) (0.99996), RMSE (0.0063) and chi square (10^{-5}). The diffusion coefficient varied between $1.0209x10^{-9}$ and $1.0440x10^{-8}$ m^2/s and the activation energy was observed to be 89.1486kJ mol^{-1} (Kane et al., 2008).

Another method for removing moisture from tea is by making use of the dry air from dehumidification process. Tea from Indonesia derived from *Camellia sinensis* were dried using the dehumidification process resulting in drying of tea leaves from weight 58gm to 47gm. (Yohana et al., 2018).

In the present study drying characteristics and mathematical modelling of drying of *Cymbopogon citrates has been investigated and different parameters viz.* Correlation coefficient (R) Root Mean Square Error (RMSE), Mean Bias Error (MBE) and Reduced Chi-Square (χ^2) evaluated.

1. Drying Characteristics and Mathematical Modeling

Thin layer drying modeling of *Cymbopogon citratus* has been investigated on the basis of twelve well known models.

Correlation coefficient (R)

The correlation coefficient, R was estimated by using the equation below and is used to test the linear relation between measured and estimated values (Gunhan el. al, 2005)

$$R^2 = \frac{\sum_{i=1}^{N}\left(M_{r_i} - Mr_{pre,i}\right) * \left(Mr_i - Mr_{exp,i}\right)}{\left[\sum_{i=1}^{N}(Mr_i - Mr_{pre,i})^2\right] * \left[\sum_{i=1}^{N}(M\,r_i - Mr_{exp,i})^2\right]}$$

Where, $Mr_{exp.\,i}$, experimental moisture ratio; $Mr_{pre,\,i}$, predicted moisture ratio and N, the total number of observations in the particular experiment.

Root Mean Square Error (RMSE)

The root mean square error may be calculated by the following equation. It provides the information on the short term performance. The value of RMSE is always positive, where zero is the value obtained in the ideal case (Gunhan el. al, 2005)

$$RMSE = \sqrt{\left[\frac{1}{N}\sum_{i=1}^{N}(M\,r_{pre,i} - Mr_{exp,i})^2\right]}$$

Mean Bias Error (MBE): The mean bias error, MBE was estimated by using the equation (Gunhan el. al, 2005)

$$MBE = \frac{1}{N}\sum_{i=1}^{N}(M\,r_{pre,i} - Mr_{exp,i})$$

Reduced Chi-Square (χ^2)

The reduced chi-square may be calculated by the following equation where *n* is the number of constants. The lower are the values are the values of the reduced χ^2,the better is the fitness of the model (Gunhan el. al, 2005).

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$$\chi^2 = \frac{\sum_{i=1}^{N} M\,r_{exp,i} - Mr_{exp,i})2}{N - n}$$

Determination of appropriate model

The characteristic drying curves are determined at three temperatures and are shown in fig 1. From the figure one can depict that the moisture content decreases with the increment of temperatures. The migration of moisture also becomes as usual rapid and takes less time with the increment of temperature. The best fitted model is selected on the basis of correlation coefficient (R^2), root mean square error (RMSE) and reduced chi-square (χ^2). The model that gives the lowest RMSE, the highest regression coefficient (R^2) efficiency values on an average while drying the products is chosen as the appropriate model. The average estimated values of correlation coefficient (R^2), mean bias error (MBE), root mean square error (RMSE), chi- square and efficiency are 0.98459, 0.005032477, 0.028091, 2.52x10⁻³ and 0.98966 were found for *Camellia sinensis*. The Midilli and Kucuk model gave the best fit and this model decides the drying attributes at temperature 30°C, 40 °C and 50 °C.

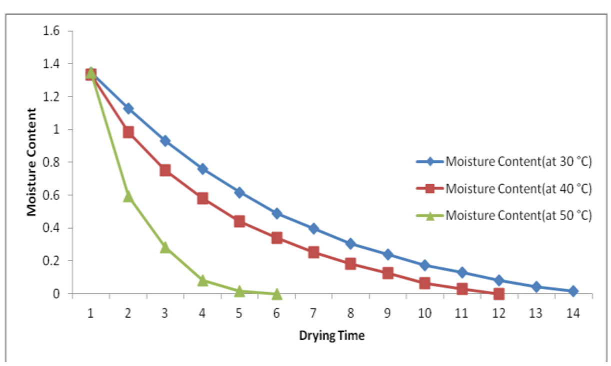

Figure .1 Variation of Moisture content with drying time *(Camellia sinensis)*

Conclusion

The drying characteristics and mathematical model of drying *Camellia sinensis* was investigated and Midilli and Kucuk model was found the best fit model of drying at selected temperatures.

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