

Drying Kinetics of Neem Seed (*Azadirachta indica*)

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Abstract: Neem (*Azadirachta indica*) is a tropical plant with good environmental adaptability. It is rich in phytochemicals and contains attributes making it suitable for large scale utilization in water purification, animal feeds and other products. Some of these attributes such as Phytochemicals, are however, known to be heat labile. Hence, the need for establishing drying parameters that will ensure the stability of the active ingredients (flavonoids, nimbin, and azadirachtin) during processing. This study therefore, investigated the drying kinetics of neem seed.

Neem seeds were dried at 30, 40 and 50 °C. Moisture Ratio (MR) and Drying Time (DT) were determined in accordance with standard procedures. The effects of each drying parameter on the drying characteristics were modelled using Verma, Henderson and Pabis, Wang and Singh, Logarithmic and Page models. Accuracy of the models was determined using the coefficient of determination (R^2), chi-square (χ^2) and Root Mean Square Error (RMSE).

The R^2 , χ^2 and RMSE values were 0.96–0.99, 6.25×10^{-4} – 3.58×10^{-3} and 0.024–0.058; 0.75–0.99, 4.93×10^{-4} – 3.09×10^{-3} , and 0.021–0.17; 0.95–0.99, 4.07×10^{-4} – 6.25×10^{-3} and 0.019–0.07 at 30, 40 and 50 °C, respectively, for the models adopted

In conclusion, the study established that logarithmic model gave the best fit for neem seed drying at 30 and 50 °C, while verma model gave a better fit at 40 °C.

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I. INTRODUCTION

Neem tree (*Azadirachta indica*) belongs to the family Mahogany known as meliaceae. It is a tropical plant that has a good environmental adaptability (Adedeji and Owolarafe, 2015). In Nigeria, Neem tree is available in several regions, such as South-Western, Northern and South Southern parts of the country. Neem tree parts are beneficial because it contains natural insecticides, cosmetics ingredients, soap, toothpaste ingredient and many other medical applications (Singh, *et al.*, 2021). Also, the tree serves as an environmental canopy in some instances with many other potential applications. However, the application of the seed in Nigeria for industrial purposes is presently limited, or perhaps there is dearth of literature in this regards.

Neem seeds are obtained from neem tree and are rich in oil. The seed kernels contain 40 to 50% by mass of non-edible oil and 20% of bio-gradable substances that are active against a wide variety of pests (Eneche *et al.*, 2019). For commercial purposes, oil and insecticides are removed from neem seed by using organic solvents. Hexane is the most common solvent used to extract oil from the seed, while ethanol is used to

extract the insecticides from de-oiled seeds according to Salami (2023). Heat transfer operation is another important method of extracting oil from oil seed, so, the knowledge on drying kinetics of the seed is essential in equipment design and in storage.

Solchansanj and Jayas. (2020) reported that drying is one of the important unit operations when processing food materials. Drying influences the quality attributes of products thus, evaluation of the drying characteristics as a function of drying conditions could help in predicting suitable parameters during drying, (Ojediran *et al.*, 2020). In recent years, several studies on the drying characteristics of various fruits, vegetables and agricultural products have been carried out. Studies reported include hazel nut (Ozdemir and Yusu Onur, 1999), bell pepper (Tunde-Akintunde *et al.*, 2005), green pepper, (Prashantha *et al.*, 2008), green bean and squash (Yaldiz *et al.*, 2001), and in each study the model that best fits the experimental data effectively documented. Therefore, this study aimed at determining the drying kinetics of moisture on its selected physical properties of neem seed.

II. MATERIALS AND METHODS

The neem fruits were obtained from neem trees located at the Faculty of Engineering and Technology, Ladoke Akintola University of Technology (LAUTECH) Ogbomoso. Collection of the fruits was done by placing nylon sheets around the stems in such a way that it covered a large cross section area as they fall down (Andrew *et al.*, 2009).

➤ Drying Characteristics

The characteristics of the product during drying was determined according to the method of Akanbi *et al.* (2006), where the dryer was kept at a fixed air velocity of 1 m/s and temperatures varied at 30, 40 and 50 °C respectively. Change in weight of a weighted neem samples was monitored at interval until there was no weight change.

➤ Moisture Ratio Determination

Moisture ratio (MR) was calculated using equation 1

$$MR = \frac{M_t - M_e}{M_i - M_e} = e^{-kt}$$

1

Where;

- M_i = the initial dry basis moisture contents (%)
- M_e = the equilibrium dry basis moisture contents (%)
- M_t = dry basis moisture content at any time 't'
- k = drying rate constant per h
- t = drying time, h

➤ Modelling of Neem seed drying

In order to describe the drying characteristics of neem seed, the drying curves (MR versus time) obtained were fitted with five semi-theoretical thin layer drying models namely – Verma, Henderson and Pabis, Wang and Singh, Logarithmic, and Page. The quality parameters of the dried neem seeds were statistically analyzed using Statistical Package for Social Scientists (SPSS) 25 software package and were subjected to analysis of variance (ANOVA). A nonlinear regression procedure for the five models was also done using (SPSS) software package. The criteria used to select the best model are the coefficient of determination (R^2), the reduced chi-square (χ^2), and root mean square error (RMSE). These criteria were used to determine the quality of the fit of the models. The model with the highest value of R^2 and the lowest values of χ^2 and RMSE were adjudged the best model to describe the thin layer drying characteristics of neem seeds. This is because the higher the values of R^2 , and the lower the values of χ^2 , RMSE, the better the goodness of fit (Doymaz, 2010; Hu *et al.*, 2016). These parameters can be calculated as follows:

$$R^2 = 1 - \frac{\sum_{i=1}^N (MR_{pred,i} - MR_{exp,i})^2}{\sum_{i=1}^N (MR_{exp,i} - MR_{pred,i})^2} \quad 2$$

$$\chi^2 = \frac{(\sum_{i=1}^N (MR_{exp,i} - MR_{pred,i})^2)}{(N-z)} \quad 3$$

$$RMSE = \left[\frac{1}{N} \sum_{i=1}^N ((MR_{exp,i}) - (MR_{pred,i}))^2 \right]^{1/2} \quad 4$$

In the above equations,

$MR_{exp,i}$ and $MR_{pred,i}$ are experimental and predicted dimensionless moisture ratios respectively;

N is number of observations;

z is number of constants.

III. RESULTS AND DISCUSSION

Fig1 showed that drying time decreased with increase in drying temperature. Moisture decrease faster at higher temperature than at low temperature, at 30 °C, the decrease in moisture was relatively lower. The downward sloping nature of the curve shows that the mechanism governing the drying process was diffusion. This agrees with the work of several authors on the drying of various food materials (Siddique and Wright, 2003; Falade and Abbo, 2007; Oyelade *et al.* 2014)

A steeper curve was observed at 50 °C showing that drying time greatly reduced with the increasing drying temperatures. This implies that there is a direct relationship between moisture content and drying time of the neem seed.

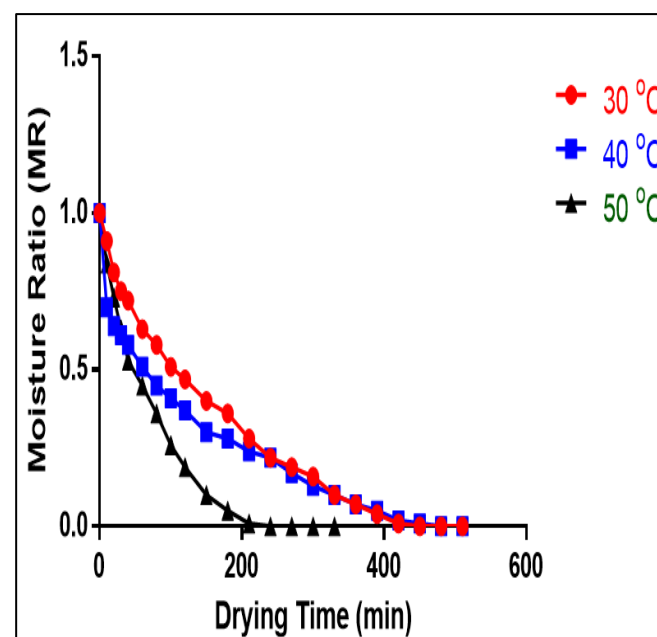


Fig 1 Moisture Ratios At Different Drying Temperatures

The plot of Ln MR against drying time shown in Figures 2, 3 and 4 showed a linear relationship and also confirms the dependence of drying time on drying air temperature. This also agrees with the work of Zingh *et al.* (2008) on water Chesnut.

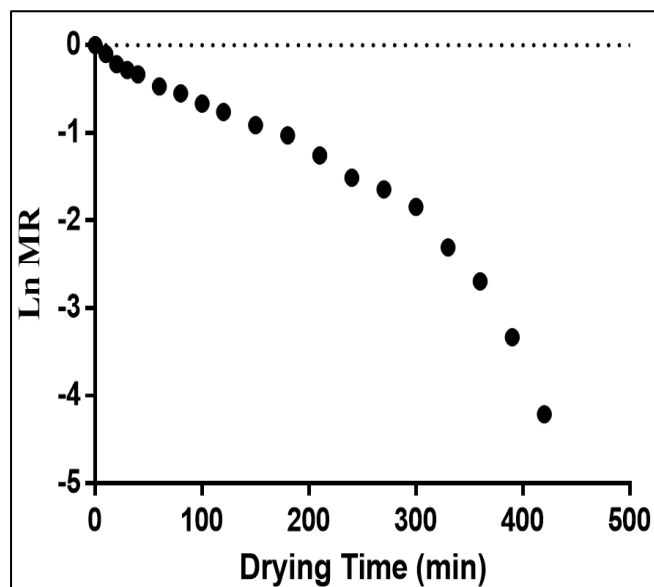


Fig 2 Plot of Ln MR against Drying Time at 30 °C

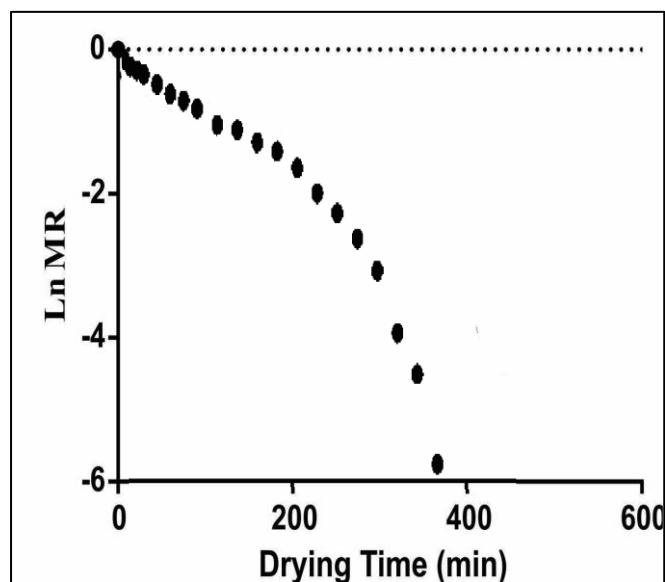


Fig 3 Plot of Ln MR against Drying Time at 40 °C

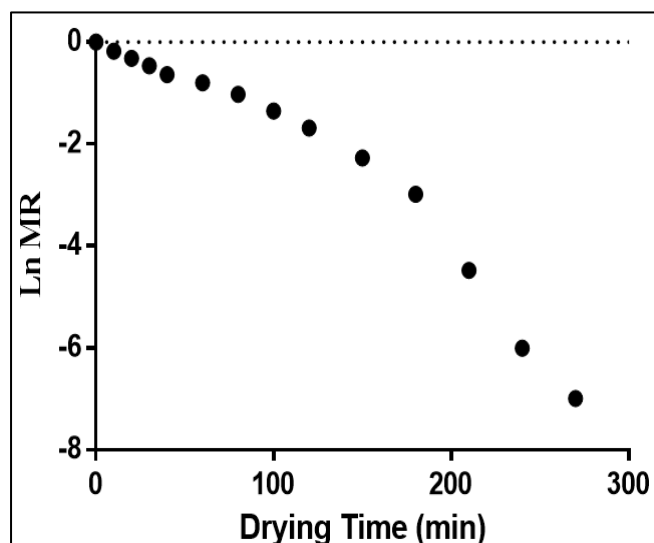


Fig 4 Plot of Ln MR against Drying Time at 50 °C

Thin layer drying models were tested to select the model that best described the drying curve equation of the neem seeds. Several authors such as Akpinar *et al.* (2005); Akpinar, (2006) have used these models in the drying of food materials. The moisture ratio obtained at different drying temperature was fitted into each of these models and by non-linear regression analysis, the value of the model contain coefficient of determination (R^2), the reduced chi-square (χ^2), and root mean square error (RMSE) were obtained. At drying temperature of 30 °C, the R^2 values ranged from 0.9646 to 0.9938, χ^2 values from 6.25×10^{-4} to 3.58×10^{-3} and RMSE from 0.0245 to 0.585. The Logarithmic model gave the highest R^2 value of 0.9938; this shows that this model successfully predicts about 99% data accuracy on neem seed drying, the model also had the lowest values for χ^2 (6.25×10^{-4}) and RMSE (0.0245). At 40 °C drying temperature, the R^2 values of the model ranged from 0.7537 to 0.9925, χ^2 values 4.93×10^{-4} to 1.81×10^{-2} and RMSE 0.0217 to 0.1721. The Verma model had the highest values of R^2 (0.9925) and lowest values for χ^2 (4.93×10^{-4}) and RMSE (0.0217). This implies that the Verma model best described the drying process at 40 °C.

At a drying temperature of 50 °C, the R^2 value of the model ranged from 0.9529 to 0.9963, χ^2 values from 4.07×10^{-4} to 1.30×10^{-3} and RMSE from 0.0195 to 0.0714, the logarithmic model had the highest values of R^2 (0.9963), lowest values of RMSE (0.0195) and lowest value of χ^2 (4.07×10^{-4}). This shows that logarithmic model best predicted the drying process at 50 °C

Overall, the Logarithmic model successfully predicted the thin layer drying of neem seed at 30 and 50 °C while Verma Model described the process sufficiently at 40 °C. In a report by Mohapatra and Rao (2005), it was assumed that R^2 values of 95 % to 98% could be assumed satisfactory. From the table, all the models studied except Wong and Singh at 40 °C had R^2 of 95%, hence they can be adjudged satisfactory in predicting the drying process. The Figures 5 to 9 show the plot of the experimental model and predicted values for each of the models. The curve also shows how well the predicted data agrees with the experimental data.

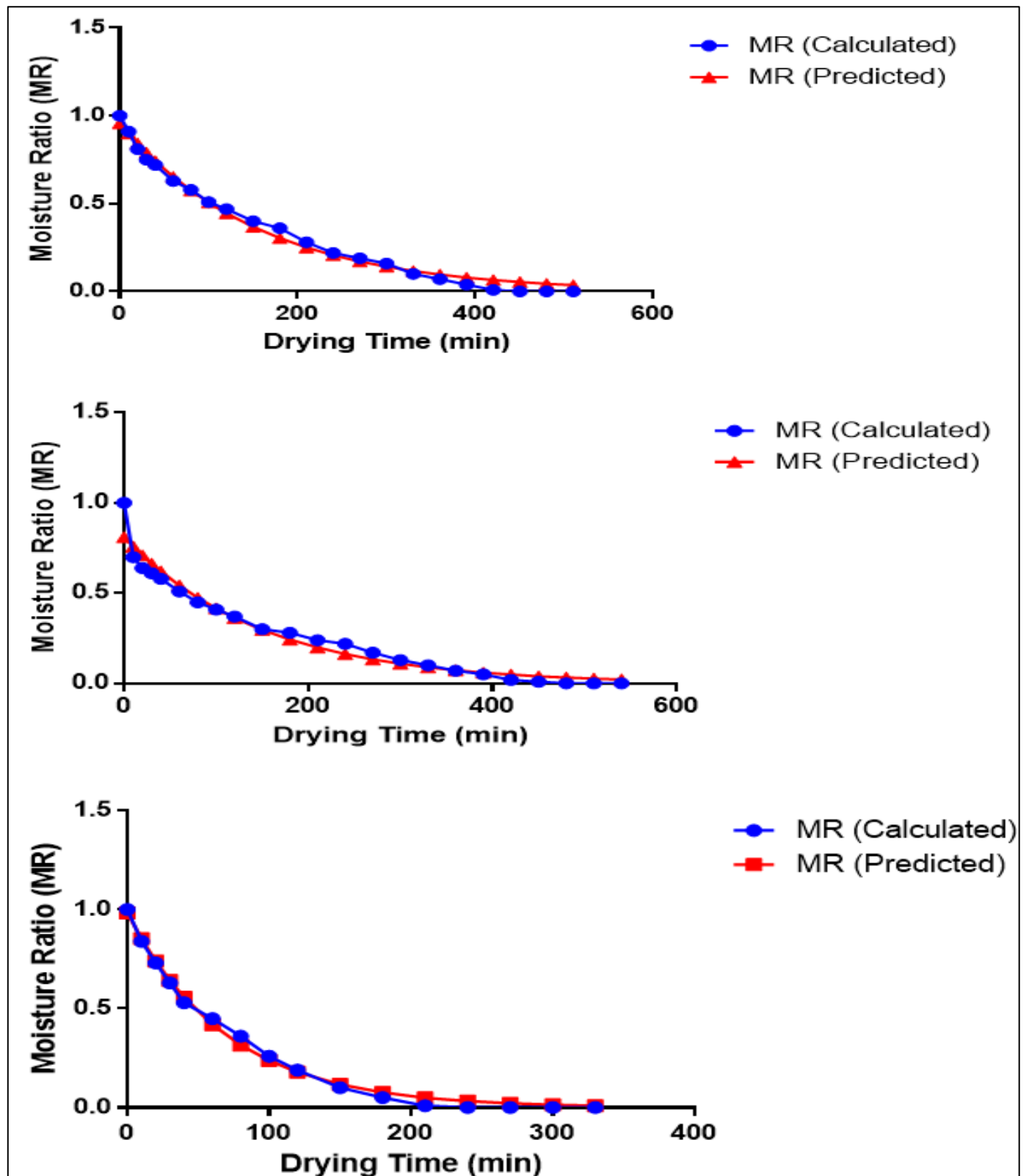


Fig 5 Experimental and Predicted Values of MR Using Henderson and Pabis Model at Temperatures of (A) 30 °C (B) 40 °C (C) 50 °C Respectively

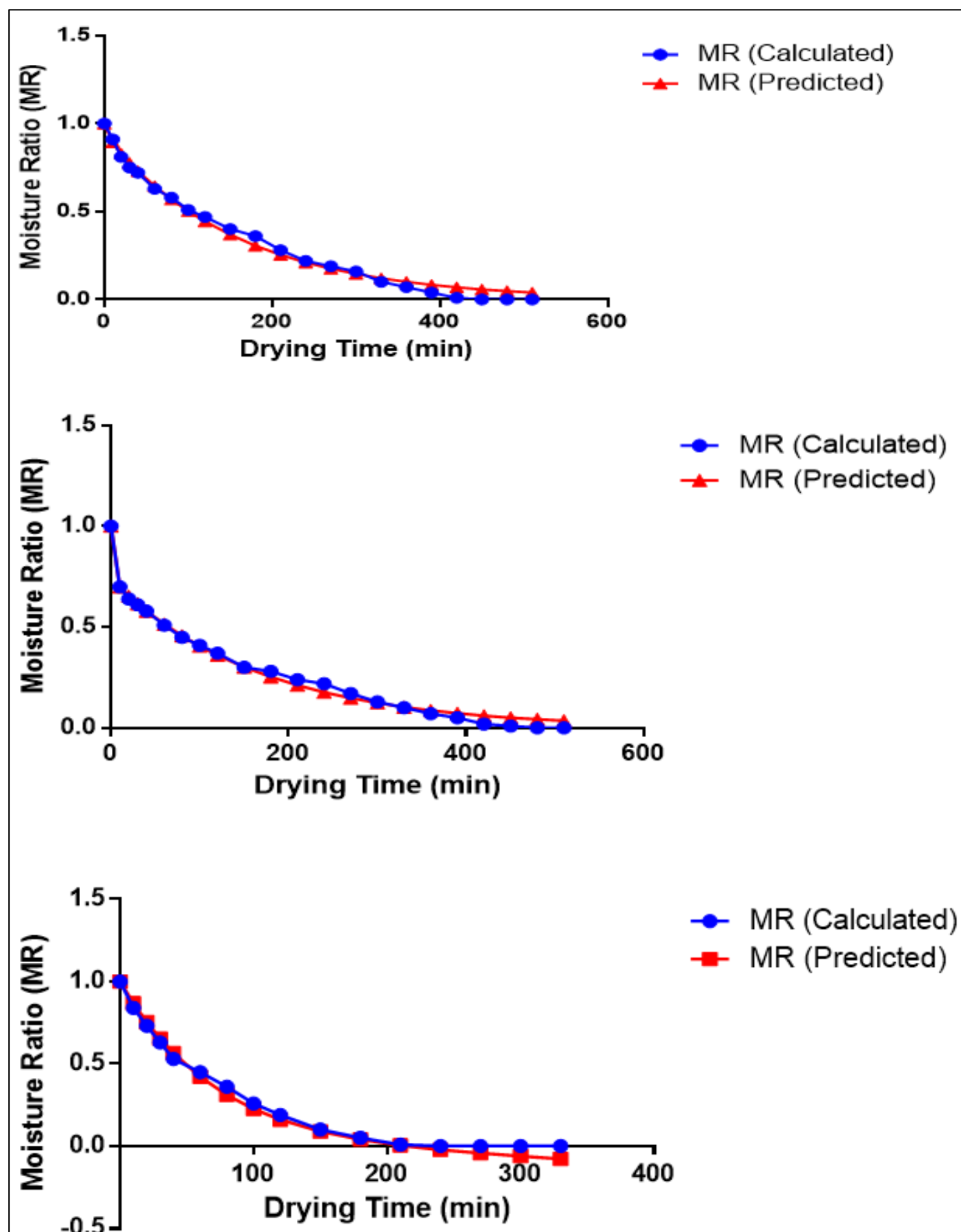


Fig 6 Experimental And Predicted Values Of MR Using Verma Model At Temperatures Of 30 °C, 40 °C And 50 °C Respectively

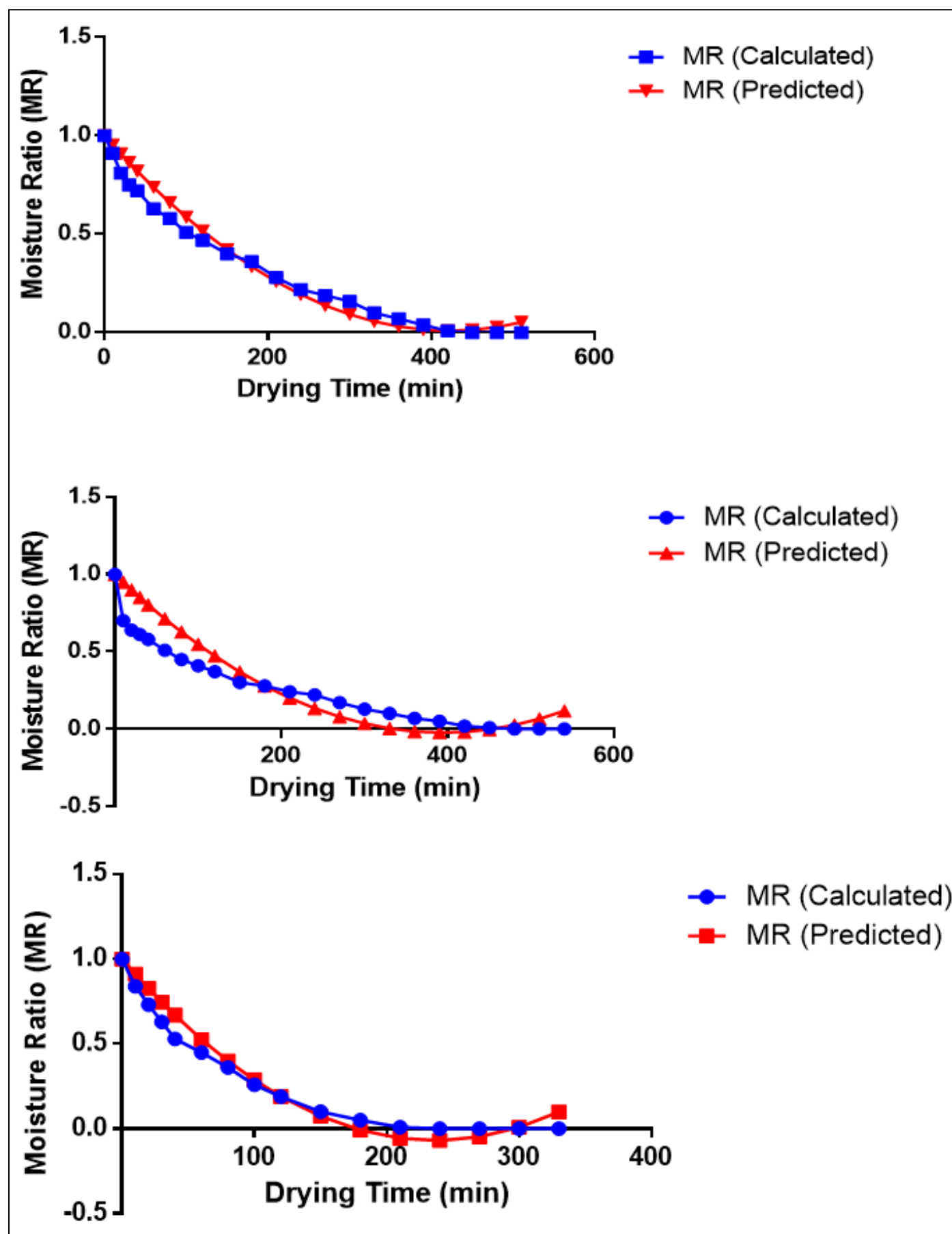


Fig 7 Experimental And Predicted Values Of MR Using Wang And Singh Model At Temperatures Of 30 °C, 40 °C And 50 °C Respectively

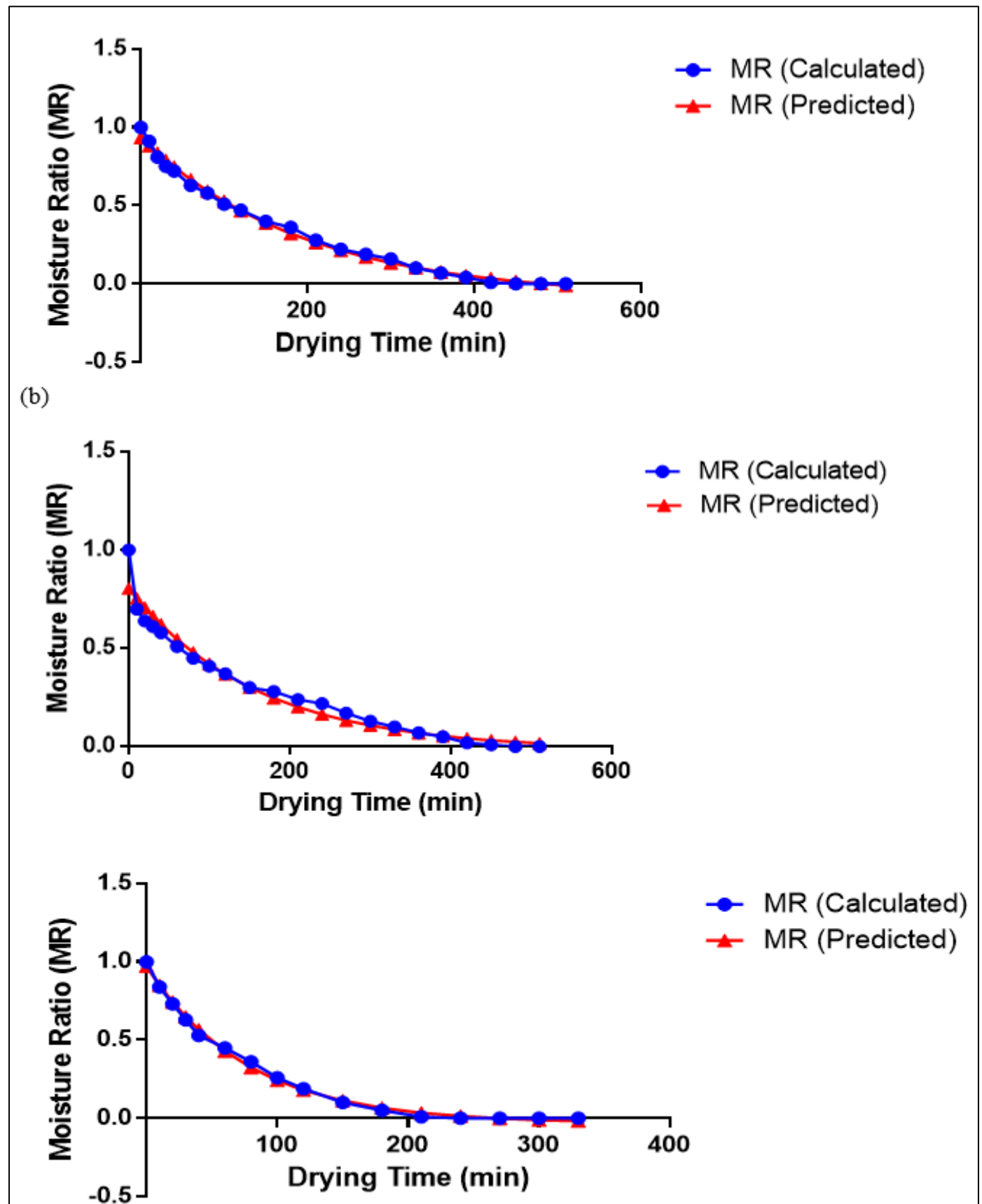


Fig 8 Experimental and Predicted Values of MR Using Log Model at Temperatures Of 30 °C , 40 °C And 50 °C Respectively.

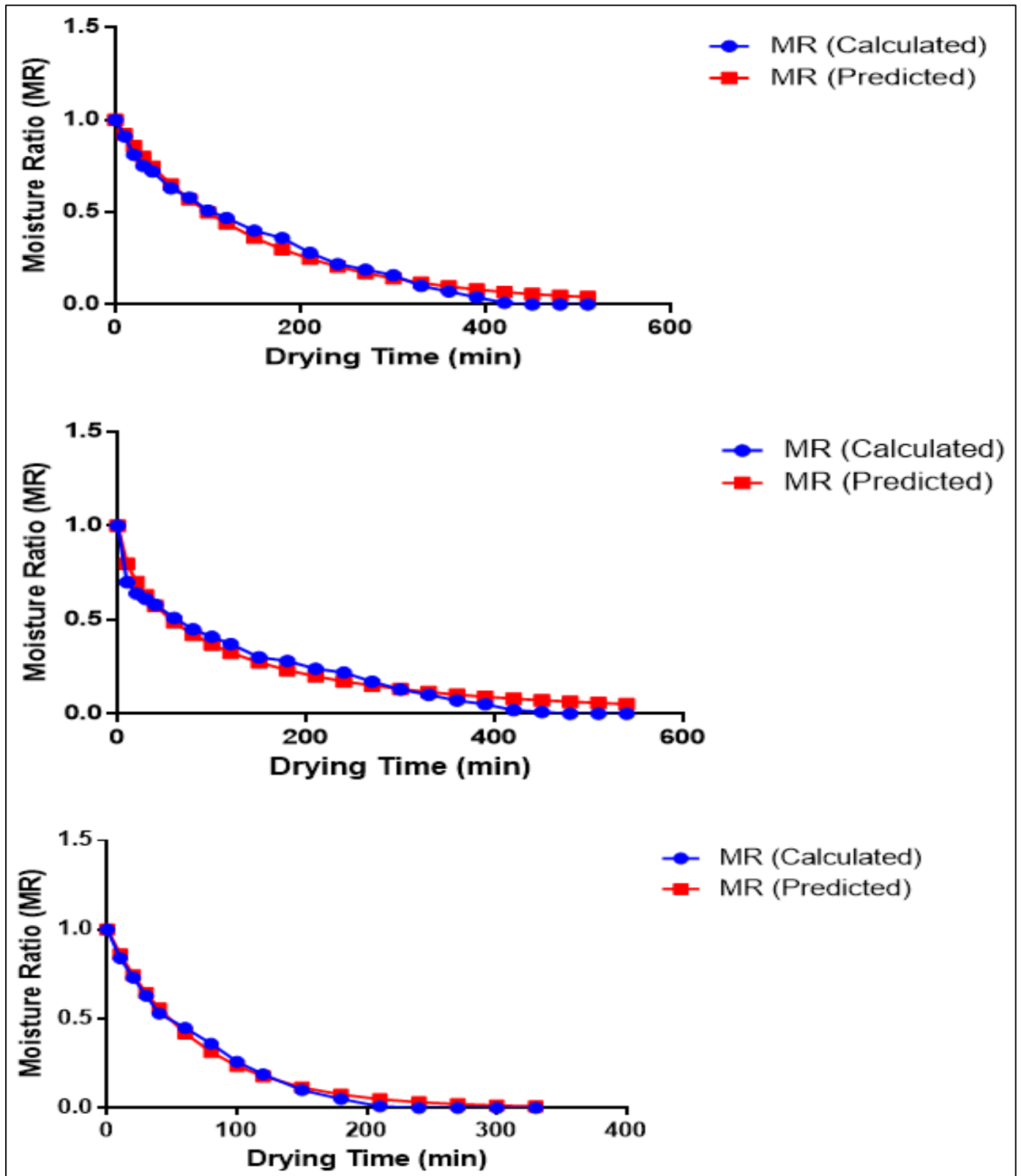


Fig 9 Experimental and Predicted Values of MR Using Page Model at Temperatures of 30 °C , 40 °C and 50 °C Respectively

IV. CONCLUSION

The drying characteristics of neem seed within the drying temperatures of 30, 40 and 50°C was also studied. It was observed that drying time decreased with an increasing drying temperature. Moisture decrease faster at higher

temperature than at lower temperature. At 30°C the decrease in temperature was relatively lower compared to 40 and 50°C. The logarithmic model gave the best fit for drying at 30 and 50°C while Verma model gave the best fit at 40°C,

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