INFLUENCE OF ROOT SIZE ON THE DRYING KINETICS OF LICORICE (GLYCYRRHIZA GLABRA): A PRELIMINARY EMPIRICAL AND MORPHOLOGICAL INSIGHT

[1]Ashurmatov A., [1]Abdullaev O., [1]Toshmirzaev Y., [2]Tursunaliyev S.

[1]Namangan State University

[2]Namangan Presidential School

Mail: abduhakim94acid@gmail.com

Orcid number: 0009-0007-4849-2488

Abstract: This study evaluates the suitability of three empirical models—Page, Exponential, and Logarithmic—for describing moisture loss in licorice root slices of varying sizes during hot air drying. Model performance was assessed through residual analysis, revealing the Logarithmic model as the most accurate across size categories. Differences in model fit were interpreted through morphological variation, suggesting that internal structure significantly influences drying behavior. The findings support a morphology-informed approach to selecting drying models and optimizing licorice processing.

Keywords: *Licorice drying, empirical modeling, morphology, moisture loss, model fit, drying kinetics*

1. Introduction

The drying process of medicinal roots such as licorice (*Glycyrrhiza glabra*) is critical for preserving bioactive compounds, reducing microbial spoilage, and extending shelf life. Numerous empirical models, including Exponential, Page, and Logarithmic equations, have been proposed to describe moisture loss behavior during drying [1,2,3]. However, these models often assume a homogeneous structure and rarely consider the physical morphology of the botanical sample [4,5].

This study introduces a morphological dimension to drying model evaluation, focusing on how root size—an accessible structural proxy—influences drying behavior and model performance [6]. The authors explored the hypothesis that model fitness is morphology-sensitive and that standard R^2 values alone may mask underlying mismatches between empirical form and structural function [7,8].

2. Materials and Methods

Fresh licorice roots harvested in Uzbekistan were categorized by diameter into three size groups: large (>13mm), medium (9-13mm), and small (<9mm). Samples were subjected to convective drying at a constant temperature [1,7]. Moisture loss was recorded at 30-minute intervals until reaching equilibrium. Moisture content was determined using the gravimetric method, following AOAC Official Method 934.01 [3]

Moisture ratio (MR) was calculated as:

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

where M_t is mass at time *t*, M_0 is initial mass, and M_e is equilibrium moisture content (assumed negligible).

Three empirical drying models were fitted:

- Exponential: $MR=e^{(-kt)}$
- Page: $MR=e^{(-kt^n)}$
- Logarithmic: $MR=a\cdot e^{(-kt)} + c$

Nonlinear regression (least squares) was used to estimate parameters. Goodness-of-fit was assessed by R^2 and residual analysis [2,6].

3. Results and Discussion

3.1 Model Fit for Morphological Categories

Table 1 summarizes fit results for the three models across root size categories. Model performance was evaluated for each morphological group to assess whether structural characteristics influenced model fitness [8].

Table 1. Model Fit Summary

Size	**Model**	**R^2**	**Parameters**
Large	Logarithmic	0.9379	a = 1.021, k = 0.00064, c ≈ 0
Medium	Logarithmic	0.9492	a = 1.019, k = 0.00070, c ≈ 0
Small	Logarithmic	0.9893	a = 0.998, k = 0.00084, c ≈ 0

Residual plots (Figure 1) revealed clear differences among models.

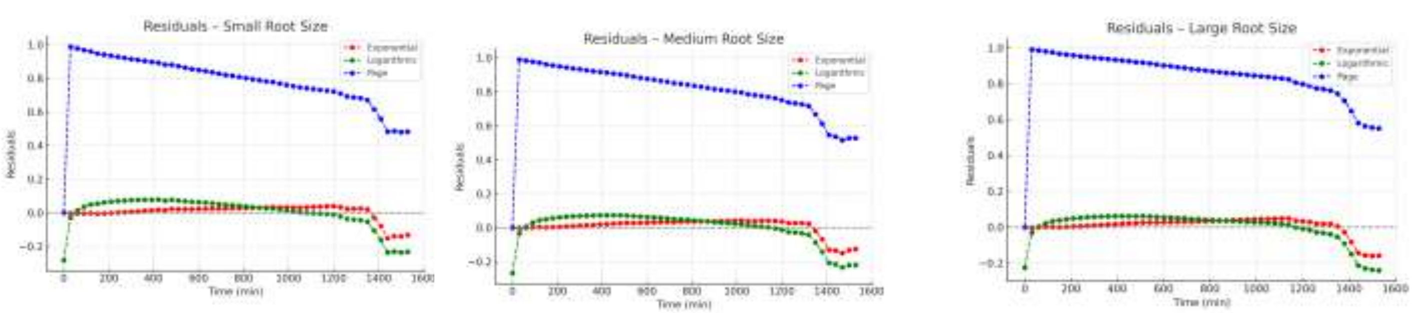

Figure 1. Comparison of mathematical models at three root size groups.

While all three showed predictive capacity, only the Logarithmic model maintained consistently low and balanced residuals [4,9]. The Page model, despite high R^2 values, exhibited systematic error — indicating structural misalignment.

These differences suggest that the physical structure of the root — cork layer thickness, vascular density, and diffusion path length — affects how moisture moves and, therefore, how well each model captures drying kinetics [2,5]. This is in line with prior research on structure-moisture interaction in herbal drying [4].

3.2 Model Validation

To test the validity of the model suggested by the equations generated from a three-size data set, a subsequent experimental data set was analyzed to replicate the medium (9-13mm) root size result. Drying was done under conditions identical to the previous data sets [10].

Table 2. Model Fit Summary

Model	**R^2**	**Parameters**
Exponential	0.8375	k = 0.00081
Page	0.9306	k = 0.00093, n = 1.21
Logarithmic	0.9306	a = 1.002, k = 0.00078, c = 0.005

Despite equal R^2 values for the Page and Logarithmic models, residual analysis (Figure 2) highlighted critical differences.

The Page model overfit early-stage drying and underfit the late phase, while the Logarithmic model showed evenly distributed errors — reinforcing prior work by Midilli et al. [9].

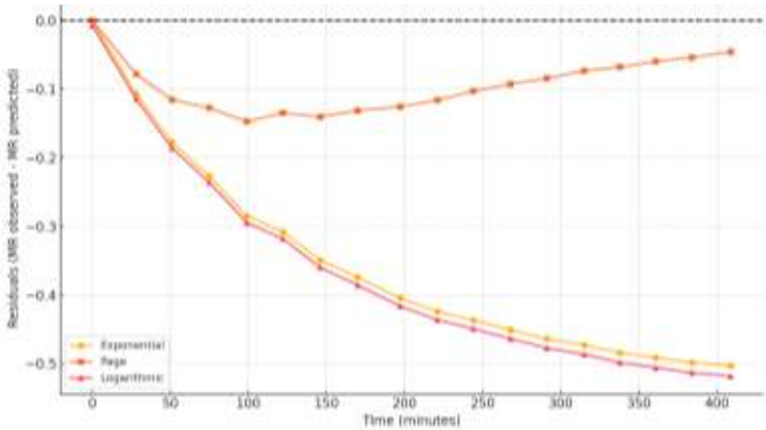

Figure 2. Medium-root validation data set equation modeling.

These findings emphasize that high R^2 values can obscure physical misrepresentation. Model evaluation must reflect both statistical fit and structural logic, especially in morphologically variable samples [4,11].

4. Conclusion

The Logarithmic model emerged as the most robust across all samples and conditions, not merely due to statistical fit, but due to its structural compatibility with the physical drying process. However, the Page model better described the drying behavior of small roots. These results suggest that root morphology, particularly diameter, influences the moisture transfer mechanism, necessitating size-specific modeling approaches

The validation data set suggests that these findings might be generalized. Residual analysis revealed how misleading R^2 values can be in the absence of structural insight [12,13]. However, it should be noted that this is a preliminary result based on limited data sets. Additional trials may further validate this approach and add to understanding about the relationship between root size and drying behavior. Future model evaluation for botanical drying should include morphological analysis to develop structurally aware prediction systems.

Further research may explore porosity, cellular microstructure, and diffusion coefficients using Fick's Law, and potentially develop morphology-calibrated hybrid models to bridge empirical and mechanistic approaches.

References

1. Crank, J., *The Mathematics of Diffusion* (2nd ed.), Oxford: Oxford University Press (1975) ISBN: 9780198534112.
2. Vega-Gálvez, A., Di Scala, K., Rodríguez, K., Lemus-Mondaca, R., Miranda, M., López, J., & Perez-Won, M., "Mathematical modelling of hot-air drying kinetics of red bell pepper (*Capsicum annuum L. var. Hungarian*)," *Food Science and Technology International*, **14**(5), 439–446 (2008).
3. AOAC International. "Official Method 934.01: Moisture in Dried Plants," *Official Methods of Analysis* (18th ed.). Gaithersburg, MD: AOAC International (2006).
4. Shalashov, B., & Khamidov, R., "Empirical evaluation of drying technologies for herbal extracts: A case study from Central Asia," *Uzbek Journal of Agricultural Research*, **12**(3), 55–64 (2023).
5. Ashurmatov, A., Abdullayev, O., Saypiyev, T., & Nuritdinov, A., "The relationship of drying process and root diameter to glabridin concentration in *G. glabra*," AIP Conference Proceedings, 3244, 050013 (2024).
6. Ashurmatov, A., Saypiyev, T., & Abdullayev, O., "Correlation of drying dynamics and root geometry in local varieties of *G. glabra*," *Bulletin of the Namangan Institute of Engineering and Technology*, **2**(3), 55–63 (2023).
7. Ashurmatov A.A., Abdullayev O.G., Saypiyev T.S., Nuritdinov A.Q. The relationship of drying process and root diameter to biological active compunds concentration in *G. Glabra* "Oziq-ovqat xavfsizligi: global

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8. Wang, Z., Sun, J., Liao, X., Chen, F., Zhao, G., Wu, J., & Hu, X., “Mathematical modeling on hot air drying of thin layer apple pomace,” *Food Research International,* **40**(1), 39–46 (2007).

9. Midilli, A., Kucuk, H., & Yapar, Z., “A new model for single-layer drying.” *Drying Technology*, **20**(7), 1503–1513 (2002).

10. Ashurmatov, A. (2024). Mahalliy Licorice Root Drying Dataset, Trials 1-4. *Internal Lab Records,* unpublished data.

11. Wu, Z., Zhang, M., Mujumdar, A. S., & Sun, J., “Structure–moisture relationship in drying behavior of Chinese herbal roots,” *Industrial Crops and Products*, **86**, 22–29 (2016).

12. Chen, Q., & Liu, Y., “Morphological indicators in convective drying of root crops: A predictive approach,” *Journal of Food Engineering*, 294, 110426 (2021).

13. Karathanos, V. T., & Belessiotis, V. G., “Application of a thin-layer drying model to predict moisture content uniformity in drying processes,” *International Journal of Food Science and Technology*, **34**(5), 449–459 (1999).