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EVALUATION OF DRYING MODELLING ON COMMON HERBS LEAVES: APPLICATION TO HIBISCUS ROSA-SINENSIS

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Abstract:

Hibiscus rosa-sinensis is well known for its medicinal benefits, particularly the leaves which are abundance in anti-inflammatory, anti-infectious, antifungal, antimicrobial, anti-diarrhoeal, antioxidant, and antipyretic activities. The medicinal plants are high in value and the post-harvest causes losses due to the reduction quality of the product. The plant can be less disposed to the damage from other microbial degradation and become manageable in storage and transport by reducing the content of moisture through drying. Drying leaves must ensure the required final moisture content that maintains the original high nutrient level as that of fresh leaves. The present review work focus on valuating the parameters associate with modelling of moisture contents and drying time for the drying method. The drying methods selected are sun drying, tray drying, oven drying and microwave drying. By making the comparison study on previous article, the parameter can be evaluated by drying rate constant which is “k” value from the best-fit drying model. The effect of the parameters of drying are temperature of drying air, thickess of spread, relative humidity, water activity and properties of different types of leaves. Also, evaluation of suitable drying model applied to Hibiscus rosa-sinensis leaves needed to understanding the drying process by selecting the most best fit model. The most suitable drying model applied are Page, Diffusion approach, Logarithm, Midilli and Two term model.

***Keywords*:**

Leaf drying, Drying methods, Drying kinetics, Mathematical modelling, Drying rate constant

Objectives:

- To evaluate the parameters associate with modeling of moisture contents and drying time for sun drying, tray drying, oven and microwave of selected herbs.
- To evaluate the suitable drying model applied to *Hibiscus rosa-sinensis* leaves.

Methodology:

The data was collected by the collection of relevant papers and articles from any databases such as Science Direct, Springer, Wiley, Sage and ResearchGate. The keywords such as drying and leaves are used to get appropriate search due to the application for drying of *Hibiscus rosa-*

sinensis leaves. These articles are selected by sort any article that relates to the selected drying methods which are sun drying, tray drying, oven drying and microwave drying. Next, the article is selected by providing or application of mathematical modelling in their research. Any journal articles that not include with this selected drying model and mathematical modelling are being excluded from this research. This is used to narrow the references of the research study for the related study. The data from the articles are being recorded and classified by their method of drying. The parameter which is the drying rate constant are being standardized to the unit per second to optimize the comparison view in this study. These articles then being analyzed on any parameter that effluence the drying by using the summary table. Lastly, the discussion are made and concluding the remarks. Also, the best fit model was recorded for each sample from the previous article to get any suggestion on suitable drying model of *Hibiscus rosa-sinensis* leaves.

Results:

Overall, this study was based on "k" value because it can identify the drying rate constant of leaves. This drying rate constant explained the evaporation rate, where the speed of moisture content decreased. A graph of temperature versus time can determine the drying rate constant. The "k" value is act as the slope of the graph while "a" values as the intercept of the line in the graph.

Table 1: Studies conducted on mathematical modelling of leaves performed by sun drying

Product / Model	Basil leaves	Bitter leaves	Bitter leaves	Crain-crain leaves	Fever leaves	Mint leaves	Parsley leaves	Soursop leaves
Newton	1.68×10^{-4}	1.151×10^{-4}	1.78×10^{-4}	1.035×10^{-4}	1.122×10^{-4}	1.49×10^{-4}	1.280×10^{-4}	0.246×10^{-4}
Page	4.18×10^{-4}	2.355×10^{-4}	113.2×10^{-4}	2.234×10^{-4}	2.839×10^{-4}	2.89×10^{-4}	3.960×10^{-4}	0.425×10^{-4}
Henderson and Pabis	1.70×10^{-4}	1.145×10^{-4}	1.63×10^{-4}	1.021×10^{-4}	1.110×10^{-4}	1.72×10^{-4}	1.38×10^{-4}	0.219×10^{-4}
Two-term	$k = 1.86\times10^{-4}$ $k_o = 205.7\times10^{-4}$	$k = 1.144\times10^{-4}$ $k_o = 1.145\times10^{-4}$	$k = 22.28\times10^{-4}$ $k_o = 1034\times10^{-4}$	N/A	$k = 1.110\times10^{-4}$ $k_o = 1.110\times10^{-4}$	$k = 1.07\times10^{-4}$ $k_o = 167.9\times10^{-4}$	N/A	$k = -0.30\times10^{-4}$ $k_o = 0.356\times10^{-4}$
Two-term exponential	203.6×10^{-4}	N/A	5.12×10^{-4}	N/A	N/A	373.1×10^{-4}	286.9×10^{-4}	N/A
Midilli et al.	N/A	1.380×10^{-4}	1132×10^{-4}	2.614×10^{-4}	2.180×10^{-4}	N/A	N/A	0.25×10^{-4}
Logarithmic	1000×10^{-4}	1.580×10^{-4}	1000×10^{-4}	1.516×10^{-4}	1.813×10^{-4}	1000×10^{-4}	1000×10^{-4}	0.55×10^{-4}
Approximation of Diffusion	129.6×10^{-4}	1.154×10^{-4}	1.63×10^{-4}	1.035×10^{-4}	1.120×10^{-4}	224.2×10^{-4}	N/A	0.25×10^{-4}

Table 2: Studies conducted on mathematical modelling of leaves performed by tray drying

Product / Model	Basil leaves	Dill leaves	Mint leaves	Moringa leaves	Lemon grass leaves
Newton	6.535×10^{-4}	170×10^{-4}	2.83×10^{-4}	0.907×10^{-4}	N/A
Page	91.73×10^{-4}	124×10^{-4}	3.83×10^{-4}	0.745×10^{-4}	0.688×10^{-4}
Henderson and Pabis	6.443×10^{-4}	188×10^{-4}	2.83×10^{-4}	0.989×10^{-4}	0.082×10^{-4}
Two-term	N/A	N/A	N/A	$k = 1.012\times10^{-4}$ $k_o = 5.830\times10^{-4}$	$k = 0.009\times10^{-4}$ $k_o = 1.387\times10^{-4}$
Two-term exponential	14.13×10^{-4}	N/A	N/A	0.907×10^{-4}	0.158×10^{-4}
Midilli et al.	N/A	53×10^{-4}	N/A	0.176×10^{-4}	19.92×10^{-4}
Logarithmic	10.31×10^{-4}	125×10^{-4}	2.83×10^{-4}	0.956×10^{-4}	0.094×10^{-4}
Approximation of Diffusion	N/A	N/A	14.67×10^{-4}	42.05×10^{-4}	0.103×10^{-4}

Table 3: Studies conducted on mathematical modelling of leaves performed by oven drying

Product / Model	Soursop leaves (T=40°C)	Bitter leaves (T=40°C)	Bitter leaves (T=60°C)	Jew's mallow leaves (T=60°C)	Spider plant leaves (T=60°C)	Thyme leaves (T=60°C)	Betel leaves (T=60°C)	Rosemary leaves (T=60°C)
Newton	0.547×10^{-4}	0.704×10^{-4}	0.936×10^{-4}	N/A	-2.83×10^{-4}	1.742×10^{-4}	5.4×10^{-4}	2.333×10^{-4}
Page	1.083×10^{-4}	1.399×10^{-4}	1.459×10^{-4}	4.083×10^{-4}	1.583×10^{-4}	1.594×10^{-4}	4.383×10^{-4}	5.833×10^{-4}
Henderson and Pabis	0.400×10^{-4}	N/A	N/A	N/A	N/A	1.799×10^{-4}	5.4×10^{-4}	2.167×10^{-4}
Two-term	$k = 3.121\times10^{-4}$ $k_o = -6.36\times10^{-4}$	$k = 0.0000$ $k_o=1.028\times10^{-4}$	$k =0.847\times10^{-4}$ $k_o=0.847\times10^{-4}$	$k = 5.816\times10^{-4}$ $k_o = 1.283\times10^{-4}$	$k = 3.3\times10^{-4}$ $k_o = 0.119\times10^{-4}$	N/A	N/A	N/A
Two-term exponential	N/A	0.946×10^{-4}	2.712×10^{-4}	N/A	N/A	N/A	N/A	N/A
Midilli et al.	1.616×10^{-4}	0.516×10^{-4}	1.381×10^{-4}	N/A	N/A	N/A	4.85×10^{-4}	N/A
Logarithmic	3.539×10^{-4}	1.028×10^{-4}	1.303×10^{-4}	4.85×10^{-4}	161×10^{-4}	1.547×10^{-4}	5.183×10^{-4}	2.333×10^{-4}
Approximation of Diffusion	0.547×10^{-4}	0.96×10^{-4}	1.707×10^{-4}	N/A	N/A	N/A	N/A	N/A

Table 4: Studies conducted on mathematical modelling of leaves performed by microwave drying

Product / Model	Thyme leave	Borage leaves	Coriander leaves	Mint leaves	Celery leaves	Pandanus leaves
Newton	143.7×10^{-4}	132.8×10^{-4}	N/A	0.258×10^{-4}	N/A	N/A
Page	124.3×10^{-4}	92.3×10^{-4}	106.1×10^{-4}	3.233×10^{-4}	N/A	0.118×10^{-4}
Henderson and Pabis	161×10^{-4}	128.8×10^{-4}	N/A	0.297×10^{-4}	N/A	0.663×10^{-4}
Two-term	N/A	N/A	$k =118.4\times10^{-4}$ $k_o=0.244\times10^{-4}$	$k =0.687\times10^{-4}$ $k_o=0.610\times10^{-4}$	N/A	N/A
Two-term exponential	N/A	N/A	N/A	994.4×10^{-4}	N/A	N/A
Midilli et al.	N/A	N/A	N/A	N/A	N/A	N/A
Logarithmic	115.9×10^{-4}	91×10^{-4}	103.7×10^{-4}	3.083×10^{-4}	0.350×10^{-4}	N/A
Approximation of Diffusion	50.7×10^{-4}	N/A	0.935×10^{-4}	1.3×10^{-4}	N/A	0.203×10^{-4}

Table 5: Studies conducted on drying model of leaves drying

Drying Method	Model	Suitability
Sun drying	Midilli model	Bitter leaves
		Crain-crain leaves
		Fever leaves
	Logarithmic model	Parsley leaves
	Approximation of diffusion model	Basil leaves
		Mint leaves
Tray drying	Logarithmic model	Basil leaves
		Dill leaves
	Approximation of diffusion model	Mint leaves
		Moringa leaves
		Lemon grass leaves
Oven drying	Midilli model	Soursop leaves
		Bitter leaves
	Logarithmic model	Thyme leaves
		Betel leaves
	Two-term model	Jew's mallow leaves
		Spider plant leaves
	Page model	Rosemary leaves
Microwave drying	Midilli model	Thyme leaves
		Borage leaves
		Mint leaves
		Celery leaves
	Page model	Pandanus leaves
	Approximation of diffusion model	Coriander leaves

Conclusion:

In conclusion, the objective of this study which is to evaluate the parameters associate with modelling of moisture contents and drying time for sun drying, tray drying, oven drying and microwave drying of selected herbs are achieved. The model constant from drying model which is "k" value can explain the parameter that affected the drying. Drying rate constant, "k" is an important reflecting the rate at which water from the leaves is removed. From this study, the increasing and decreasing value of "k" is affected by the temperature of drying air, relative humidity, thickness of spread, water activity and properties of different types of leaves which are size and thickness of leaves. The second objective which is to evaluate the suitable drying model applied to *Hibiscus rosa-sinensis* leaves also achieved. The most suitable drying models are Page model, Midilli model, approximation of diffusion model, logarithmic model and two-term model.