

The influence of microwave drying on drying and rehydration kinetics of *Acanthus ilicifolius* leaves in tea production

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Abstract

Acanthus ilicifolius, commonly known as Jeruju, is a medicinal herb found in Malaysia, recognized for its anti-inflammatory and antioxidant properties, making it an ideal candidate for healthy tea. This study investigated the crucial drying and rehydration processes of *Acanthus ilicifolius* leaves in tea production, focusing on drying kinetics and characteristics. Utilizing microwave drying with varying power levels, four mathematical models; Page, logarithmic, Newton, and Midili and Kucuk were employed to analyze drying behaviour, while Peleg and first-order kinetic models were applied to the dried leaves in powder form for a rehydration behaviour assessment. Results demonstrate microwave drying at 1000 W as the fastest, taking only 20 min, while commercial shade drying requires 72 hrs. The Page model best fits the drying behaviour, showing higher R^2 values (0.9840-0.9999) and lower X^2 values (0.0007-0.0048) for both methods. Microwave drying process preservation yields the lowest a^* value of -4.16 ± 0.61 , and microwave drying post-commercial drying exhibits a DPPH inhibition value of 23.84%. In the rehydration process of the dried leaves, the first-order kinetic model proves most suitable with higher R^2 values (0.8998-0.9943). The study emphasizes the significant impact of the drying method on *Acanthus ilicifolius* leaves, offering valuable insights for optimizing tea production with this medicinal herb.

1. Introduction

A brief literature review and previous relevant work with references. *Acanthus* is one of the plant species that grows in mangrove forests (Abdel-Aziz *et al.*, 2016). *Acanthus ilicifolius* L. locally known as Jeruju belongs to Acanthaceae family and is classified as a true mangrove species that can be found in India, the West Pacific Islands and Southeast Asia like Malaysia, Cambodia and Indonesia (Ragavan *et al.*, 2015; Aisiah *et al.*, 2022). It has gained attention as it is used in Indian and Chinese medications. In India, the tender shoots and leaves were used to treat snake bites while in China, the roots were used to treat paralysis and asthma (Patel *et al.*, 2020). Besides, *Acanthus ilicifolius* has been traditionally used in treating boils and wounds (Govindasamy and Arulpriya, 2013). Furthermore, the ethanol extraction of this plant's leaves has been proven to kill *P. acne* bacteria (Nusaibah *et al.*, 2021). It has the potential to be utilised as a healthy tea that has antioxidant tea to fight stress-related disease and the ability to purify blood (Abdel-Aziz *et al.*, 2016; Patel *et al.*, 2020). The extraction of *Acanthus ilicifolius* can be done by drying,

powdering and storing the plants in containers (Baishya *et al.*, 2020).

Due to the belief in herbal medicine's safety and efficacy, there is a rising demand for plant-derived medications, seen as a safer alternative to costly pharmaceuticals with potential side effects. For instance, numerous clinical issues with the treatment of infectious diseases and the commonly used antibiotics are occasionally linked to unfavourable effects like host immunosuppression, hypersensitivity, and allergic reactions (Panda *et al.*, 2009). Hence, there is a pressing need to find natural antimicrobial agents. *Acanthus ilicifolius* has a lot of antimicrobials and anti-inflammatory activities that can be utilised in healthy herbal tea production (Mani Senthil Kumar *et al.*, 2008; Govindasamy and Arulpriya, 2013). Herbal consumption methods encompass various options, such as steeping the herbs in hot water or ingesting them as powders, pills, paste, or pellets. Additionally, traditional methods involve drying the herbs for preservation, followed by rehydration with water to enjoy them as tea while ensuring their availability for future consumption.

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The drying process significantly influences the quality of *Acanthus ilicifolius* tea production, impacting its physical and chemical properties (Xiangyang et al., 2010). Proper drying procedures and controls are essential to maintain tea quality and optimize energy usage (Xiangyang et al., 2010). The evaluation of tea quality includes assessing its structural, visual, rehydration, and nutritional characteristics (Leung, 2007).

Hot air drying, a common convective method for herbs, has drawbacks like being time-consuming, energy-intensive, and affecting product quality (Cheenkachorn et al., 2022). Researchers explore alternatives like microwave drying, which reduces drying time for various herbs (Arslan and Musa Özcan, 2008; Ng et al., 2021).

To optimize the rehydration process, maintaining an adequate moisture content is crucial. Dried herbal leaves with low moisture content experience slower rehydration due to prolonged water absorption (Mujaffar and Lee Loy, 2017). The particle size of the tea significantly impacts the rehydration and nutritional characteristics (Vuong et al., 2011). Reducing the particle size enhances the surface area, facilitating the transfer of active principles from the plant material to the solvent (Handa, 2008). Ground tea samples in a previous study exhibited a 36% higher content of myricetin, quercetin, and kaempferol compared to unground tea samples (Makanjuola, 2017).

The utilization of microwave drying and rehydration for tea production with *Acanthus ilicifolius* leaves remains limited. The objectives of this study were to investigate the drying characteristics and kinetics of *Acanthus ilicifolius* leaves with microwave drying and to study the rehydration characteristics and kinetics of dried *Acanthus ilicifolius* leaves in the production of tea.

2. Materials and methods

2.1 Materials

Fresh *Acanthus ilicifolius* leaves and the commercial (shade dried) *Acanthus ilicifolius* leaves that are dried for 72 h were obtained from Gold Oceans Farms located in Banting, Selangor.

2.2 Pre-treatment of raw materials

Pre-treatment of fresh *Acanthus ilicifolius* leaves was done to remove dirt and insects as well as retain the nutritional value of the leaves as steam blanching significantly increases the DPPH scavenging activity in the production of herbal tea from *Moringa oleifera* leaves (Wickramasinghe et al., 2020). The leaves were

cleaned from dirt using tap water. The samples were then steam blanched at 95°C for 15 s and immersed in ice-water bath for another 15 s to prevent the leaves from being overcooked (Ng et al., 2021). The leaves were then dab-dried using tissue.

2.3 Drying of *Acanthus ilicifolius* leaves

For microwave drying, microwave oven (NN-C2003S, Panasonic, Japan) was used in this study. Blanched *Acanthus ilicifolius* leaf weight around 1.5 - 2 g was spread on the microwave tray and dried at 270, 600 and 1000 W until it achieved constant weight loss. The weight was monitored by weighing the samples every 4 min intervals.

2.4 Mathematical modelling of drying curves

For mathematical modelling, the equation in Table 1 was applied to choose the best model for describing the drying behaviour of *Acanthus ilicifolius* leaves. The coefficient of determination (R^2), root mean square error (RMSE) and chi-square (X^2) were calculated to evaluate the goodness of fit of the models. The models that best described the drying process of *Acanthus ilicifolius* leaves give the highest value of R^2 closes to 1 and the lowest value of RMSE closes to 0. The highest R^2 and lowest RMSE value demonstrates that the models closely align with the observed drying behaviour (Zielinska and Michalska, 2016).

Table 1. Mathematical models applied to the drying curves.

Model no.	Equation	Model name
1	$MR = a \cdot \exp(-kt) + c$	Logarithmic
2	$MR = \exp(-kt^n)$	Page
3	$MR = \exp(-kt)$	Newton
4	$MR = a \cdot \exp(-kt^n) + bt$	Midili and Kucuk

2.5 Rehydration of dried *Acanthus ilicifolius* leaves

The dried *A. ilicifolius* were grounded and sieved using a 100 µm mesh sieve size. The tea powders were categorized as coarse powder (Dankowska and Kowalewski, 2019). Approximately 2±0.05 g of the grounded *Acanthus ilicifolius* leaves from all drying methods were put into a tea bag and soaked in 250 ml at 85°C of distilled water for 15 min (Puspitowati and Driscoll, 2007). The experiment was repeated by using 2±0.05 g of dried *Acanthus ilicifolius* leaves. The reading is recorded every 3 min on the leaves' moisture.

2.6 Mathematical modelling of rehydration curves

In the context of mathematical modelling, the First Order Kinetic and Peleg equations listed in Table 2 were employed to select the optimal model for describing the rehydration behaviour of dried *Acanthus ilicifolius*

leaves. Evaluation of the model fit was conducted through the calculation of key statistical indicators, specifically R^2 , RMSE and X^2 . The models that most accurately depicted the drying process of *Acanthus ilicifolius* leaves exhibited R^2 values approaching unity and RMSE values nearing zero.

Table 2. Mathematical models applied for the rehydration curves.

Model no.	Equation	Model name
1	$M = M_e + (M_o - M_e) \times \exp(-k_{r1}t)$	First order kinetic
2	$M = M_o + \frac{1}{k_1 + k_2 \times t}$	Peleg

2.7 Colour measurement

The colour of *Acanthus ilicifolius* leaves samples before and after drying was measured using a portable colourimeter (WR10-8, Shenzhen Wave Optoelectronics Technology Co. Ltd., China). The leaf colour was determined by three readings on three different sides of the leaf; upper, middle and lower parts of the leaves. The L, a* and b* values were obtained from the average of the three readings. The colour brightness coordinate L*, which ranges from black at 0 to white at 100, measures the whiteness value of a colour. The chromaticity coordinates a* measures red when positive and green when negative, and coordinate b* measures yellow when positive and blue when negative (Arslan and Musa Özcan, 2008).

2.8 Antioxidant analysis

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) inhibition assay is usually employed to assess the antioxidant activity in plants. *Acanthus ilicifolius* leaves, dried using a microwave oven operating at 600 W, have been selected for comparison with commercially available dried *Acanthus ilicifolius* leaves. This choice was made because both sets of samples yield superior tea infusions and exhibit improved appearances in terms of tea colour and the colour of the leaves after the drying process. It's worth noting that the infusion obtained from the 1000 W microwave showed a greenish colour, attributed to the higher power intensity, which led to the deterioration of colour pigments. The three samples were extracted using ethanol solution for DPPH analysis. A 0.1 mL of the ethanol extraction was mixed with 80% ethanolic 0.6 mM DPPH solution. The absorbance of the mixture at 515 nm was measured using a UV-vis spectrophotometer. The percentage of inhibition of the ethanol extract of dried *Acanthus ilicifolius* plants was calculated by using the equation 1 (Salar et al., 2015):

$$\% \text{ inhibition} = \frac{A_0 - A_1}{A_0} \times 100 \quad (1)$$

where A_0 is the absorbance of the control and A_1 is

the absorbance of the reaction mixture.

3. Results and discussion

3.1 Microwave drying of *Acanthus ilicifolius* leaves

3.1.1 Drying curves and drying rates

The drying curves of *Acanthus ilicifolius* leaves subjected to microwave drying at three different power levels; 270 W, 600 W and 1000 W are illustrated in Figure 1. It can be seen from the graph that higher microwave power resulted in a shorter drying time. Drying of *Acanthus ilicifolius* leaves that was conducted at 1000 W exhibited the shortest drying time, 20 mins followed by drying power at 600 W; 24 mins and 270 W; 32 mins. The initial moisture content of the leaves, $78.16 \pm 0.04\%$ was reduced to $7.94 \pm 0.73\%$, $6.70 \pm 0.09\%$ and $5.81 \pm 0.35\%$ at 270 W, 600 W and 1000 W, respectively. The previous study on drying Misai Kucing leaves and roots using the microwave vacuum technique supports the notion that microwave power affects the drying time (Ismail and Amin, 2016). The reduction of drying time might be due to the higher microwave intensity that led to faster moisture removal of the samples. Figure 2 illustrates the drying rate curve of microwaves at different power levels (W). The drying rate curve showed the relationship between the drying rate and moisture content of the samples. During the early stage of drying, where the moisture content of the sample is high, the drying rate is at peak. As the moisture content decreases, the drying rate becomes slower as the samples lose their moisture. At the microwave power

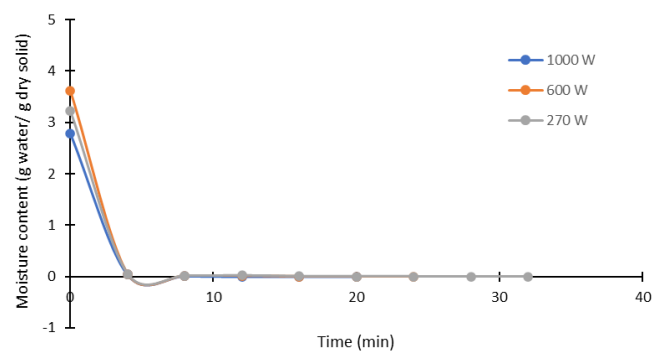


Figure 1. Drying curves of *Acanthus ilicifolius* leaves at different microwave drying powers (W).

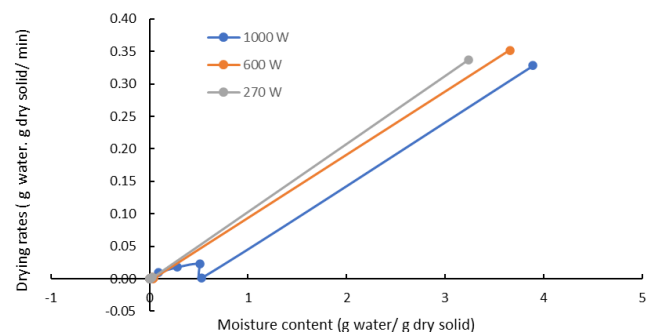


Figure 2. Drying rates curve of *Acanthus ilicifolius* leaves at different microwave powers (W).

270 W and 600 W, the drying rate decreased gradually as the moisture content decreased. However, the drying rate varies at microwave power 1000 W. Overheating and uneven drying process of the samples might led to this observation.

3.1.2 Drying kinetics of *Acanthus ilicifolius* leaves

Four different drying models, Page, Logarithmic and Midili and Kucuk and Newton model were used to describe the drying kinetics of *Acanthus ilicifolius* leaves. The constant value, R^2 , RMSE and X^2 are shown in Table 3. The values were calculated by using SOLVER in Microsoft Excel.

The models that best described the drying process of *Acanthus ilicifolius* leaves give the highest value of R^2 close to 1 and the lowest value of RMSE close to 0. The highest R^2 and lowest RMSE values demonstrate that the models closely align with the observed drying behaviour

(Zielinska and Michalska, 2016). All the models fit the experimental data perfectly as the range of R^2 value was between 0.9840-0.9999 and the RMSE value was between 0.0007-0.0048. Based on Table 3, all the models can be utilized to describe the microwave drying behaviour of the leaves. However, the Page model was the best model to fit the drying kinetics of 270 W, 600 W and 1000 W as this model exhibits the highest R^2 values ranging between 0.9938-0.9999 and the lowest RMSE values ranging between 0.0008- 0.0263. These findings were correlated with previous studies that said Midili Kucuk and Page best describe the behaviour of rosemary drying using microwave oven (Arslan and Musa Özcan, 2008b). Page model was also said to be the best-predicted model for drying of *Acanthus ilicifolius* leaves using hot air drying (HAD) (Bualuang et al., 2022).

In the Page model, as the microwave power increases, the k constant decreases. This shows that

Table 3. The drying constant of different drying models: Page, Logarithmic, Newton, Midili and Kucuk Model for microwave drying at different power levels (W).

Model	Microwave power (W)	R^2	RMSE	X^2	Model constant
Page	270	0.9999	0.0008	7.84×10^{-4}	k = 1.4007 n = 0.0095
	600	0.9999	0.0031	1.30×10^{-5}	k = 1.0213 n = 0.1138
	1000	0.9938	0.0263	9.67×10^{-4}	k = 1.0213 n = 0.4278
Logarithmic	270	0.9999	0.0007	8.29×10^{-7}	k = 1.1893 a = 0.7633 c = 0.2367
	600	0.9999	0.0035	2.01×10^{-5}	k = 1.2338 a = 0.9934 c = 0.0046
	1000	0.9861	0.0392	2.69×10^{-3}	k = 0.5236 a = 0.9604 c = 0.0383
Newton	270	0.9970	0.0019	3.80×10^{-3}	k = 0.1485
	600	0.9998	0.0049	2.68×10^{-5}	k = 1.1175
	1000	0.9786	0.0488	2.80×10^{-3}	k = 0.4309
Midili and Kucuk	270	0.9999	0.0032	1.81×10^{-3}	k = 1.0000 a = 1.0001 b = 1.18×10^{-5} n = 1.0001
	600	0.9997	0.0050	4.95×10^{-5}	k = 1.0002 a = 1.0000 b = 1.42×10^{-4} n = 1.0003
	1000	0.9840	0.0421	4.13×10^{-3}	k = 0.7436 a = 1.0672 b = 6.93×10^{-4} n = 0.6442

higher microwave power led to the reduction of drying time due to the rapid evaporation rate. Figure 3 (a-d) shows the comparison between experimental data and predicted data for all four applied models, Page, Logarithmic, Newton and Midili and Kucuk respectively. As for the drying behaviour, when drying occurs at a higher microwave power; 600 W and 1000 W, the drying proceeded directly to the falling rate stages. These results were in accordance with a previous study on the drying of *Acanthus ilicifolius* leaves at 600 W and 700 W power of microwave that stated the drying process has no constant rate period (Bualuang et al., 2022).

3.2 Comparison between shade-dried *Acanthus ilicifolius* leaves with microwave heating method

3.2.1 Comparison of colour measurement

The colour parameters, especially the greenness of the samples, are an important quality attribute. The changes in greenness during various drying methods of *Acanthus ilicifolius* leaves are illustrated in Table 4. The colour of dried *Acanthus ilicifolius* leaves at different drying methods is displayed in Table 5. The increased a* value indicated a reduction in the greenness. The greenness of the microwave drying sample at 270W was the highest, -4.16 ± 0.61 , compared to shade drying.

Blanching led to a remarkable doubling of the greenness in the leaves. The a* value of microwave samples increased as the microwave power increased. This result showed a similar trend with the drying of *Acanthus ilicifolius* leaves using microwave drying and microwave vacuum drying (Bualuang et al., 2022). The increase of a* value may be due to the damage to the sample surface because of high microwave power which led to the degradation of the chlorophyll content. Besides, the reduction of greenness during the drying process may occur due to the decomposition of colourants, chlorophyll, and carotenoids caused by a browning reaction (Zielinska and Michalska, 2016). As a result, microwave power at 600W can be considered the most ideal method in preserving the greenness of *Acanthus ilicifolius* leaves. The a* value of shade-dried was higher compared to other methods, 44.50 ± 0.39 . The positive value indicates that shade-dried *Acanthus ilicifolius* leaves become red and brownish colour as seen in Table 4 after drying. This result was in accordance with Patel et al. (2020).

The b* value that indicates the yellowness of the samples is illustrated in Table 4. The increase in b* value indicates the increase in yellowness of the samples. The

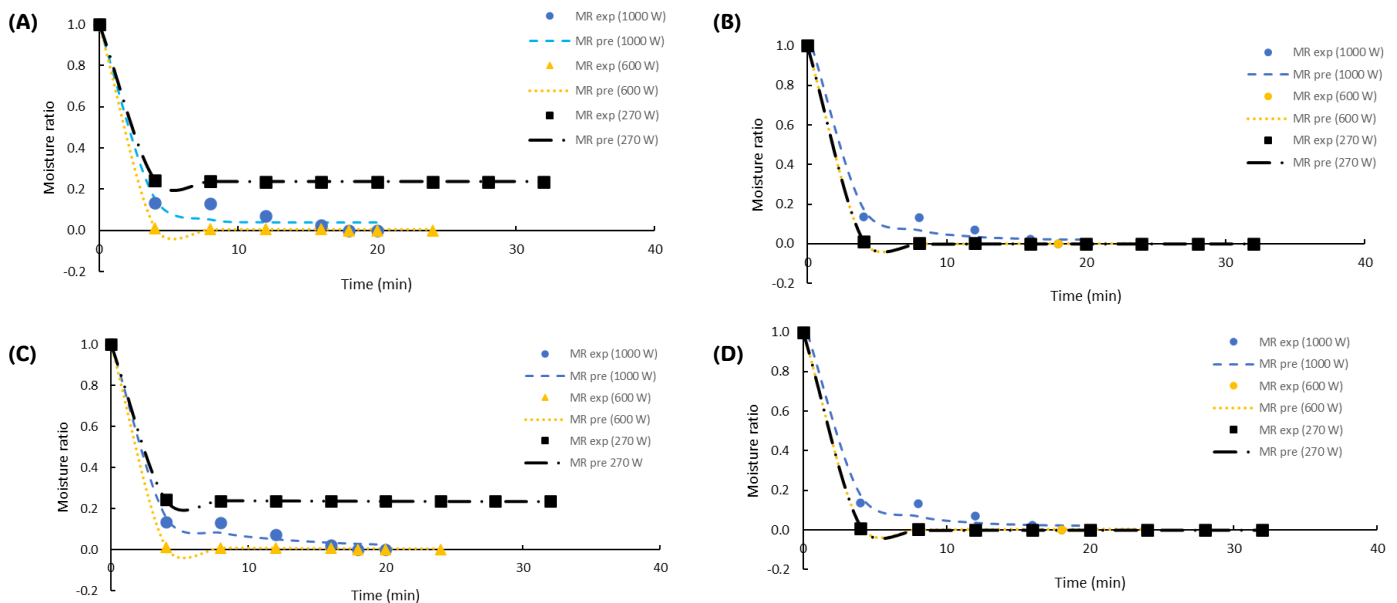


Figure 3. Comparison between experimental and predicted data for (a) Page model, (b) Logarithmic model, (c) Newton model and (d) Midili and Kucuk model for microwave drying at different power levels (W).





Table 4. Comparison of colours between blanched leaves, commercial-shade dried and microwave dried leaves.

Drying method	L*	a*	b*	a*/b*	ΔE
Blanched leaves	37.11±0.68 ^c	-8.05±0.76 ^d	43.54±0.43 ^{cd}	-0.19±0.02 ^e	
Shade drying	19.58±0.69 ^f	44.50±0.39 ^a	52.63±2.09 ^c	0.85±0.03 ^a	56.22±0.90 ^b
Microwave drying					
270 W	45.50±0.34 ^a	-4.16±0.6 ^{bc}	47.98±1.03 ^{cd}	-0.09±0.01 ^{cd}	10.34±0.66 ^c
600 W	43.12±0.71 ^{ab}	-3.78±0.15 ^{bc}	41.31±1.54 ^d	-0.10±0.01 ^d	7.81±0.97 ^c
1000 W	41.96±0.69 ^b	-2.69±0.65 ^b	41.62±1.38 ^d	-0.06±0.20 ^{bcd}	7.69±0.13 ^c

Values are presented as mean±SD. Values with different superscripts in the same column are statistically significantly different (P<0.05). L: brightness (+100)/darkness (+0), a: redness (+50)/greenness (-50) coordinate, b: yellowness (+50)/blueness (-50) coordinate, C: chroma, ΔE: colour differences.

b* value does not give a significant difference, especially at microwave power at 600 W and 1000 W; 41.31 ± 1.54 and 41.62 ± 1.38 , respectively.

Table 5. Comparison of colours between blanched leaves, commercial dried *Acanthus ilicifolius* leaves with microwave drying.

Drying methods	Commercial dried leaf (shade drying)	Microwave power (W)		
		270	600	1000
Colour of dried leaves				

The a*/b* value is one of the important qualities in dried products. The a*/b* values are illustrated in Table 4. Microwave at 600 W samples exhibited the lowest a*/b* values, -0.10 ± 0.01 compared to the other drying method employed. This observation highlights the preferential nature of microwave drying at 600 W power, as lower a*/b* values are highly desirable in the context of dried products (Arslan and Musa Özcan, 2008). Shade-dried samples gave undesirable quality as the a*/b* value is the highest, 0.85 ± 0.03 compared to other drying methods. Uncontrollable temperature during the shade drying process might contribute to this observation.

3.2.2 UV-vis spectrophotometer of dried *Acanthus ilicifolius* leaves

The tea infusions of *Acanthus ilicifolius* powder dried at microwave drying (600 W) and shade drying were subjected to UV-Vis spectra at 200 - 450 nm using UV-Vis spectrophotometer (Genesys 180, Thermo Fisher Scientific, MA, USA). The absorption of light intensity at 200 - 450 nm was observed to check the presence of phenolic compounds in the samples. Figure 4 illustrates the absorption band of shade-dried powder leaf samples through microwave drying at 600 W. The absorption bands for the tea infusion samples were visible in the range of 200-370 nm, as seen in Figure 4. This

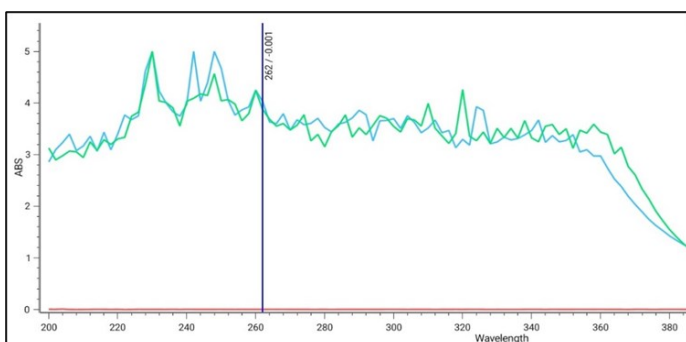


Figure 4. The comparison of the absorption band of tea infusion samples using shade and microwave drying. Green line: microwave drying, blue line: shade drying.

observation suggests the presence of phenolic compounds in the tea infusion samples, as these absorption bands are associated with phenolic compounds (Dankowska and Kowalewski, 2019). The absorbance of light in the range of 200-370 nm at shade-drying samples is higher compared to microwave drying. This shows that more phenolic compounds were present in the shade-drying samples. The result was in accordance with the previous study of drying Misai Kucing leaves where the shade drying method showed the highest total phenolic content compared to sun drying and air drying at 40°C (Thamkaew et al., 2021).

3.2.3 Assessment of antioxidant activity of dried *Acanthus ilicifolius* leaves

Table 6 below shows the percentage of DPPH inhibition using ethanol extraction between *Acanthus ilicifolius* leaves dried using microwave at 600 W and shade drying. The shade-dried *Acanthus ilicifolius* leaves gave the highest percentage of DPPH inhibition, 35.63%. The percentage of inhibition observed in *Acanthus ilicifolius* leaves dried using a microwave oven at 600 W is slightly lower, at around 24%, showing a reduction of 33% compared to the commercial drying method. The lower value of DPPH inhibition in microwave drying might be due to the intensity of microwave power that led to the reduction of phenolic compounds. The increase of phenolic compounds in the samples increased the DPPH inhibition, which led to an increase in antioxidant activity. The observations were in accordance with the previous studies that stated that the presence of phenolic compounds is responsible for the antioxidant activity of plants (Chizzola et al., 2008; Guerrero-Beltran and Baquero, 2014). Phenolic compounds exhibit high efficiency in scavenging DPPH free radicals due to their rapid electron transfer mechanism, with hydrogen atom abstraction playing a less significant role (Foti et al., 2004). Therefore, the drying method that best preserved the phenolic compounds in the samples is shade drying followed by microwave drying. However, shade drying requires a longer drying time that might not be suitable for mass-scale production.

Table 6. Comparison of DPPH inhibition between shade drying and microwave drying (600 W) of *Acanthus ilicifolius* leaf.

Drying methods	DPPH inhibition (%)
Microwave oven drying (600 W)	23.84
Shade drying	35.63

3.3 Rehydration of *Acanthus ilicifolius* leaves powder

3.3.1 Rehydration kinetic for microwave drying method

Dried *Acanthus ilicifolius* leaves were subjected to rehydration, and two rehydration models, Peleg's and

First Order Kinetic were used to analyse the rehydration behaviour. Table 7 exhibits the values of the parameters of R^2 , RMSE, X^2 , M_E and the rehydration constant of Peleg and First Order Kinetic Model for dried *Acanthus ilicifolius* powder, respectively. As seen in Table 7, the model that describes the best rehydration behaviour for *Acanthus ilicifolius* powder using microwave drying is the First Order Kinetic Model as it has the highest R^2 values, ranging between 0.8998-0.9962, compared to Peleg Model. The plot of experimental data and predicted data of the First Order kinetic model and Peleg model were illustrated in Figure 5 (a-b). First-Order Kinetic model was identified as the best model due to its ability to closely align with the experimental data obtained which can be seen in Figure 5 (a). The rate constant, k_{RI} of the First Order Kinetic model does not give significant differences as the microwave power increased until 600 W. The insignificant differences in k_{RI} were in accordance with the rehydration of microwave drying of *Ficus carica* Linn leaves (Yilmaz et al., 2023). The rate constant, k_{RI} at 1000 W power increased from 0.2994 to 0.4795 min^{-1} . The results were in accordance with the study on the rehydration of tomatoes where the rate constant of the first-order kinetic model decreased at 350 W and 500 W; from 0.057467 to 0.052314 min^{-1} and then increased gain at 650 W; from 0.052314 to 0.092312 min^{-1} (Ndisanze and Koca, 2022). Peleg Model gives inconsistent values of R^2 , RMSE and X^2 . In Figure 5 (b) the experimented data deviates significantly from the predicted model data.

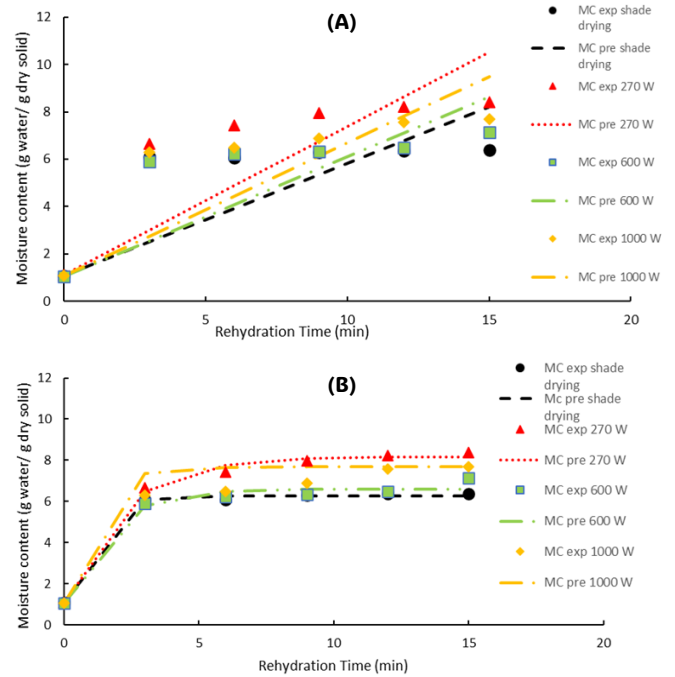


Figure 5. Comparison between experimental and predicted data for (a) first-order kinetic model for *Acanthus ilicifolius* powder and (b) peleg model for *Acanthus ilicifolius* powder at shade drying and different microwave power temperatures (W).

In previous studies, the first-order kinetic model has been identified as the best-fitted model for the rehydration of microwave-dried *Ficus carica* Linn leaves (Yilmaz P et al., 2023). Furthermore, during the analysis of the rehydration behaviour of microwaved (450 W, 720 W and 900 W) dried *Thunbergialaurifolia* Linn. leaves, a

Table 7. The rehydration constant of different drying models; first order kinetic, peleg for shade dried and microwave dried *Acanthus ilicifolius* powder at different power levels (W).

Model	Microwave power (W)	R^2	RMSE	X^2	Model constant
First order kinetic	Shade dried	0.9937	0.1009	0.0153	$k_{RI} = 1.0774$ $M_E = 6.2825$
	270	0.9943	0.1921	0.0554	$k_{RI} = 0.4765$ $M_E = 8.1717$
	600	0.9815	0.2778	0.1557	$k_{RI} = 0.6488$ $M_E = 6.6023$
	1000	0.8998	0.7168	0.7707	$k_{RI} = 1.0000$ $M_E = 7.6806$
Peleg	Shade dried	0.0215	1.9081	5.4612	$a = 2.1079$ $b = 0.0005$ $M_E = 1924.8540$
	270	0.3231	2.0879	6.5388	$a = 1.8992$ $b = 0.1023$ $M_E = 10.8750$
	600	0.2437	1.7749	4.7254	$a = 1.9989$ $b = 0.0057$ $M_E = 175.3339$
	1000	0.3235	1.8625	5.2033	$a = 1.9893$ $b = 0.0589$ $M_E = 18.0467$

medicinal herb that can be found in Thailand and other Southeast Asian countries, First-order kinetic model exhibited high R^2 values ranging between 0.98-0.99 (Phahom *et al.*, 2017). Based on these findings, the first-order kinetics model can be regarded as a reliable rehydration model for describing the rehydration kinetics of microwave-dried *Acanthus ilicifolius* leaves.

4. Conclusion

In the drying process of *Acanthus ilicifolius* leaves, microwave drying is indeed a faster technique compared to the commercial shade drying method, which excels in preserving phenolic compounds and showcasing the highest DPPH inhibition. However, shade drying's impracticality for mass production due to its 72-hour drying time makes microwave drying a more viable option despite its potential reduction in phenolic compounds, crucial for antioxidant activity and blood purification. Microwave drying maintains the leaves' beneficial properties and preserves their greenness, with the Page model as the most appropriate fit. In the rehydration process of the dried leaves, the first-order kinetic model proves most suitable for *Acanthus ilicifolius* powder obtained through microwave drying, highlighting its superior absorbency in water due to particle size effects.

Conflict of interest

The authors declare no conflict of interest.

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