



Research article

COMPARATIVE ANALYSIS OF INFRARED AND CONVENTIONAL OVEN DRYING ON THE KINETICS, EFFECTIVE MOISTURE DIFFUSIVITY AND SHRINKAGE OF CALAMANSI (*CITRUS MICROCARPA*)

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ABSTRACT

Calamansi (*Citrus microcarpa*) is a Southeast Asian citrus fruit valued for its distinctive sour taste and bioactive compounds. However, its high moisture content contributes to rapid deterioration, making drying an important preservation method. Drying is a common preservation technique that lowers water activity and enhances the stability of food. This study investigated the effect of infrared (IR) and oven drying at 50, 60, 70, and 80 °C on the drying kinetics, effective moisture diffusivity, and shrinkage of calamansi slice. The results showed that higher temperatures and the use of the IR dryer led to a faster drying rate. Five thin-layer drying models -Newton, Page, Modified Page, Henderson and Pabis, and Midilli were fitted to the experimental moisture ratio data to describe the drying behaviour. The effective moisture diffusivity values were found to range from 0.35×10^{-8} to 5.05×10^{-8} m²/s and generally increased with drying temperature. Shrinkage increased at higher drying temperatures and was more pronounced during IR drying. The Midilli model nevertheless demonstrated high flexibility across IR and high temperature oven drying, achieving $R^2 \geq 0.999$ at IR drying at 60 °C and oven drying at 80 °C. Overall, IR drying provided moisture removal faster than conventional oven drying of calamansi slices under the investigated conditions.

1. Introduction

Calamansi (*Citrus microcarpa*), a small citrus fruit native to Southeast Asia, is widely cultivated and consumed in countries such as the Philippines and Malaysia. It is a natural hybrid of mandarin and kumquat (Cheong et al., 2012) and is prized for its aromatic, tangy juice, which is commonly used in beverages, marinades, dipping sauces, and traditional culinary

preparations. Despite its growing popularity, Calamansi remains highly perishable due to its high moisture content (85–90 %) and delicate peel structure. Seasonal overproduction often leads to significant post-harvest losses, as the fruit deteriorates quickly without proper preservation. This short shelf life limits its availability and increases food waste,

particularly in regions with insufficient cold-chain infrastructure.

Nutritionally, Calamansi is a rich source of vitamin C and various bioactive compounds, including phenolics and flavonoids, which contribute to its antioxidant capacity and associated health benefits (Carr & Maggini, 2017). Preservation of Calamansi not only extends its marketability beyond harvest season but also retains its functional properties, supporting the development of value-added products in the nutraceutical, beverage, and cosmetic sectors (Ma et al., 2017).

Drying is one of the most widely employed preservation methods for fruits, offering enhanced shelf stability by lowering water activity and inhibiting microbial and enzymatic degradation (Kondareddy et al., 2019). Conventional hot-air drying, while effective, is often associated with long drying times, uneven heat distribution, shrinkage, and considerable energy consumption due to indirect convective heat transfer. To overcome these drawbacks, alternative drying technologies such as fluidized bed, microwave, osmotic, and infrared (IR) drying have been developed. Among these, infrared drying has garnered increasing interest in the food industry due to its rapid heating mechanism, energy efficiency, and potential to better preserve color, texture, and nutrient content.

Infrared radiation penetrates food surfaces, inducing molecular vibration and volumetric heating, which accelerates moisture diffusion and evaporation. This method has shown promising results in the dehydration of various food materials, including fruits, vegetables, herbs, and grains (Sakare et al., 2020). Studies comparing hot-air and infrared drying techniques have demonstrated that IR drying can significantly reduce drying times while improving rehydration capacity and maintaining better physical and nutritional qualities (Abidin et al., 2025; Li et al., 2021; Nwakuba et al., 2021; Oshima et al., 2021; Rojas et al., 2019; Alwi et al., 2017). However, excessive IR exposure can cause surface hardening or color degradation, requiring precise process control (Alwi et al., 2022).

Despite these developments, information on the IR drying behaviour of calamansi remains limited. Most previous studies examined other fruits or citrus species, which differ from calamansi in terms of fruit size, peel structure, composition and internal moisture distribution. In particular, limited comparative information is available on the drying kinetics, moisture transport and shrinkage of calamansi subjected to IR and conventional oven drying over different temperatures. Mathematical modelling of its drying behaviour also remains insufficiently reported despite its importance predicting moisture removal. Therefore, this study aimed to compare the drying kinetics of calamansi using IR and oven drying at 50, 60, 70 and 80 °C; evaluate the suitability of selected thin-layer drying model; determine the effective moisture diffusivity and assess the resulting shrinkage. This work provides calamansi specific drying data and identifies the differences between IR and oven drying under the investigated conditions.

2. Materials and methods

2.1. Materials

2.1.1. Plant Material and Sample Preparation

Fresh Calamansi (*Citrus microcarpa*) fruits were purchased from a local market in Shah Alam, Malaysia. Fruits of similar size, shape, colour and apparent maturity without visible damage were selected and rinsed with distilled water. Each fruit was cut with a stainless-steel knife into circular slices of 10 mm thickness and approximately 25 mm diameter and the seeds were removed. The weight for each slice was approximately 3.0 ± 0.2 g, with the initial moisture content determined gravimetrically. The prepared slices were immediately sealed in airtight polyethylene containers and stored at 4 °C prior to the drying experiment.

2.2. Drying Procedures

2.2.1. Infrared Drying

Infrared drying was conducted in a custom-fabricated (IR) dryer with ceramic emitters. Three infrared heaters were installed inside the vessel made of ceramic tubes and installed with a fiber wire with a current voltage of 240 V and

a frequency of 50 Hz. Two mineral-insulated thermocouple Type K sensors were used to monitor and set the temperature during drying. For each drying run, five samples were arranged in a single layer on the stainless tray without overlapping. Drying was conducted at 50 °C, 60 °C, 70 °C, and 80 °C. The samples were weighed at intervals of 10 minutes using a balance with an accuracy of 0.001 g and drying was terminated when the mass change between two consecutive measurements was constant (approximately less than 0.01g).

2.2.2. Oven Drying

For comparison, a forced-convection oven (Memmert GmbH, Germany) was used under identical temperature settings (50–80 °C). Slices were similarly arranged on trays and dried until constant weight. Similarly, each drying temperature was tested with five replicate samples. The oven was preheated at the desired temperature prior to the drying experiments. Sample mass was recorded at 10-min intervals and the same endpoint criterion used for IR drying (mass change <0.01g between two consecutive measurements) was applied.

2.3. Drying Characteristics

2.3.1 Moisture Content

At each drying time, moisture content on a dry basis MC_{db} (g water/g dry matter) was calculated using the equation:

$$\text{Moisture Content}(MC_{db}) = \frac{M_w - M_{db}}{M_{db}} \times 100 \quad (1)$$

where m_w is the wet sample mass (g) and m_{db} is the dry weight (g) of the sample determined at the drying endpoint.

2.3.2. Drying Rate and Moisture Ratio

The dimensionless moisture ratio (MR) and drying rate (DR) were calculated at 10-minute intervals as follows:

$$\text{Moisture Ratio (MR)} = \frac{M_t - M_e}{M_0 - M_e} \approx \frac{M_t}{M_0} \quad (2)$$

$$\text{Drying Rate (DR)} = \frac{M_{t+\Delta t} - M_t}{\Delta t} \quad (3)$$

where M_0 , M_t , $M_{t+\Delta t}$, and M_e are the initial, current, subsequent and equilibrium moisture contents on a dry basis respectively and Δt is the measurement interval. Because M_e was small relative to M_0 , MR was approximated as M_t/M_0 .

2.3.3. Drying Kinetics Modeling

Nonlinear regression analysis was performed using Microsoft Excel Solver® to fit experimental MR data to five common thin-layer drying models as shown in Table 1.

Table 1. Thin-layer drying models used in this study

Model Name	Model Equation
Lewis	$MR = \exp(-kt)$
Page	$MR = \exp(-kt^n)$
Modified Page	$MR = \exp[-(kt)^n]$
Henderson & Pabis	$MR = a \exp(-kt)$
Midilli	$MR = a \exp(-kt^n) + bt$

Model performance was evaluated based on the coefficient of determination (R^2), reduced

chi-square (χ^2), and root mean square error (RMSE) as shown in Table 2.

Table 2. Statistical metrics used for model validation

Metric	Formula
Coefficient of Determination (R^2)	$R^2 = 1 - \frac{\sum (MR_{\text{exp}} - MR_{\text{pred}})^2}{\sum (MR_{\text{exp}} - \bar{MR}_{\text{pred}})^2}$
Chi-Square (χ^2)	$\chi^2 = \sum \frac{(MR_{\text{exp}} - MR_{\text{pred}})^2}{N - n}$
Root Mean Square Error (RMSE)	$RMSE = \sqrt{\frac{1}{N} \sum (MR_{\text{exp}} - MR_{\text{pred}})^2}$

The model exhibiting the highest R^2 and the lowest χ^2 and RMSE values was considered the most suitable for describing calamansi drying behaviour (Kim et al., 2021).

2.3.4 Effective Moisture Diffusivity (D_{eff})

Effective moisture diffusivity was estimated using Fick's second law of diffusion for slab geometry. The moisture ratio was modeled using the simplified form:

$$MR = \frac{8}{\pi^2} \exp\left(-\frac{\pi^2 D_{\text{eff}} t}{4L^2}\right) \quad (4)$$

Taking the natural logarithm:

$$\ln(MR) = \ln\left(\frac{8}{\pi^2}\right) - \frac{\pi^2 D_{\text{eff}} t}{4L^2} \quad (5)$$

D_{eff} was calculated from the slope of $\ln(MR)$ versus time. The characteristic length (L) was taken as half of the initial slice thickness ($L = 0.005$ m). The slab approximation was adopted because moisture transport was assumed to occur predominantly through the

two broad faces of the 10-mm thick, approximately 25-mm diameter slices.

2.3.5. Shrinkage Measurement

Shrinkage was evaluated as a percentage reduction in mass before and after drying:

$$\text{Shrinkage}(\%) = \frac{m_i - m_f}{m_i} \times 100 \quad (6)$$

where m_i and m_f are the initial and final sample masses, respectively. Samples were allowed to cool to ambient temperature prior to final weighing.

2.4. Data analysis

Drying curves were fitted by nonlinear regression using Microsoft Excel Solver. Model performance was assessed using R^2 , RMSE and χ^2 .

3. Results and discussion

3.1. Calamansi Drying Time

Drying time decreased as temperature increased for both methods. At 80 °C, IR drying reached the endpoint after approximately 130 min, whereas oven drying required approximately 310 min. IR drying at 50 °C produced a drying duration broadly comparable with oven drying at 80 °C as shown in Figure 1. These observations demonstrate faster moisture removal by IR compared to conventional oven. Compared with oven drying, the shorter processing time achieved by IR drying at 50 °C

may reduce cumulative thermal exposure and potentially improve the retention of heat-sensitive constituents. Previous studies have similarly shown that IR drying can shorten processing time relative to oven drying and that appropriately selected IR temperatures may help preserve antioxidant activity in plant materials (Alwi et al., 2025).

The shorter drying time achieved by IR drying can be attributed to the penetration and absorption of radiant energy within the surface and near-surface regions of the sample. The absorbed energy excites molecular vibrational modes, particularly those associated with water, producing rapid heating and steeper temperature and moisture gradients. These gradients enhance internal moisture diffusion towards the surface and accelerate evaporation (Sakare et al., 2020).

3.2. Drying Characteristics

3.2.1. Moisture Content Profiles

Figure 1 illustrate the moisture ratio profiles of calamansi slices dried by infrared (IR) and conventional oven methods across a temperature range of 50–80 °C. In all conditions, moisture content declined progressively over time, with

more pronounced reductions at elevated temperatures. This behavior is further reflected in the moisture ratio (MR), a dimensionless indicator of relative moisture loss, which also decreased with time in all cases. IR drying exhibited a steeper decline in both moisture content and MR during the initial stages, particularly at 80 °C, highlighting its higher drying intensity and efficiency.

As drying progressed, the rate of moisture removal slowed considerably, indicating a shift into the falling-rate period—characterized by internal moisture diffusion as the controlling mechanism. The falling-rate period was longer for oven-dried samples, particularly at lower temperatures. IR drying at 80 °C achieved significant moisture reduction and a sharp drop in MR within the first two hours, whereas oven drying required up to five hours to reach a comparable MR level. These trends are consistent with the drying behavior of biological materials, where water becomes increasingly bound within the cellular matrix as drying continues (Bolaji et al., 2021; Ampah et al., 2022).

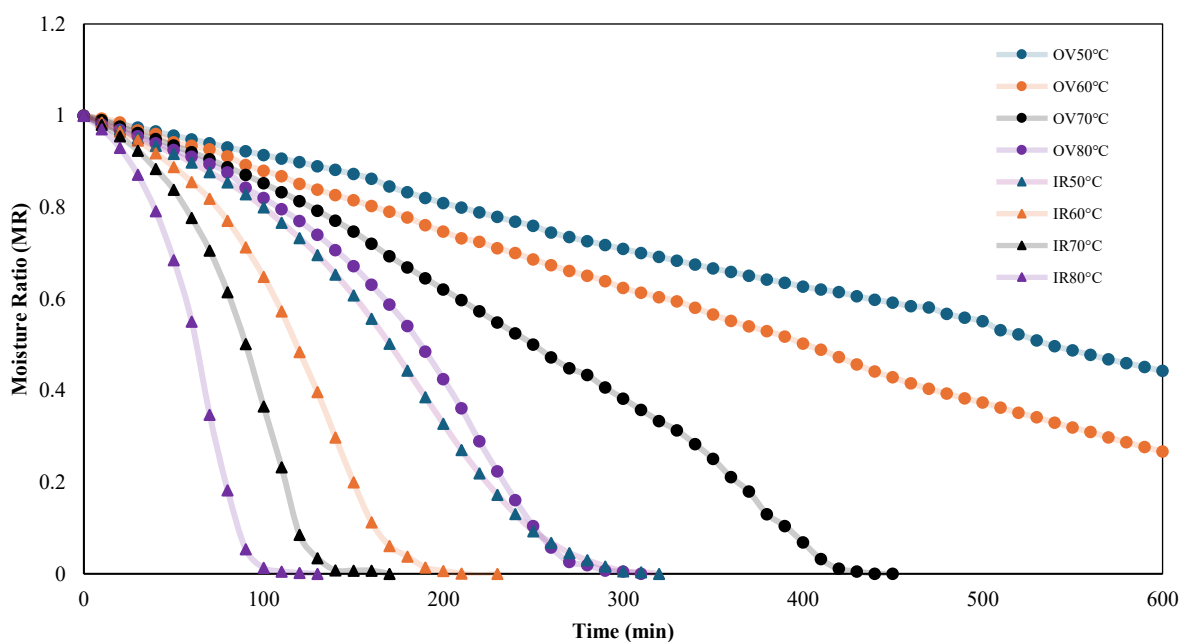


Figure 1. Moisture ratio of dried calamansi under influence of IR and conventional oven drying at various temperatures; 50 °C, 60 °C, 70 °C, 80 °C.

3.2.2. Drying Rate Analysis

Figures 2 and 3 show drying rate as a function of moisture content for IR and oven drying respectively at 50, 60, 70 and 80 °C. For IR drying (Figure 2), the highest observed drying rate occurred at 80 °C (approximately 0.13 g water/g dry matter.min) followed by 70,

60 and 50 °C. This ordering reflects the greater heat- and mass-transfer driving forces at higher temperatures and the rapid absorption of IR radiation by the exposed sample layers, which enhances heating, internal moisture diffusion, and surface evaporation (Sakare et al., 2020; Abdullah et al., 2022).

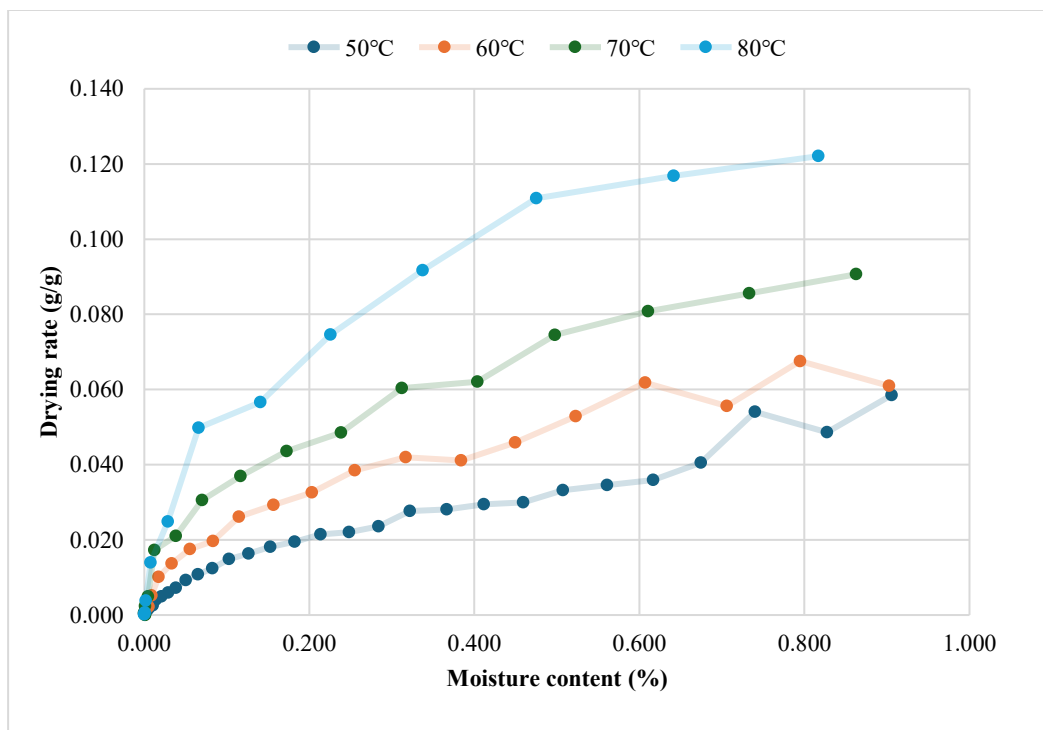


Figure 2. The relationship between drying rate (g/g) and moisture content (%) of Calamansi slices dried using an infrared (IR) dryer

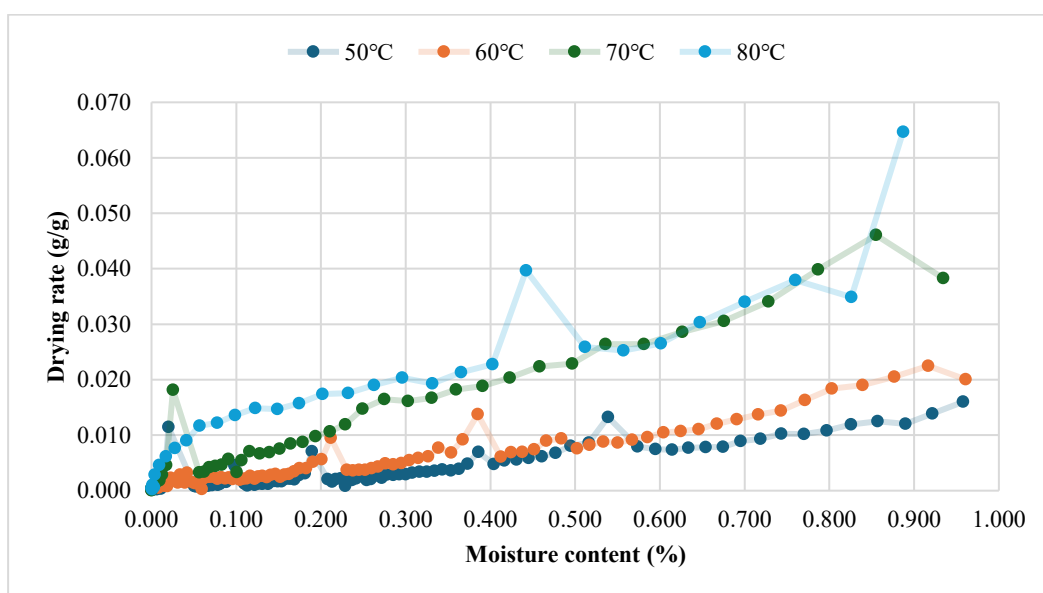


Figure 3. The relationship between drying rate (g/g) and moisture content (%) of Calamansi slices dried using conventional oven.

The drying rate generally decreased as moisture content declined, confirming predominantly falling-rate behaviour. Free and readily available moisture was removed first, whereas the later stages depended increasingly on internal diffusion of more strongly bound water. The observed kinetic trends agree with reports of accelerated moisture removal during IR drying of sliced plant materials (Çağlar & Selvi, 2020; Rojas et al., 2019; Younis et al., 2018).

In contrast, the oven drying data in Figure 3 displayed lower drying rates across all temperatures, with a maximum drying rate of approximately 0.07 g/g at 80 °C. Moreover, the curves were more scattered and irregular, indicating non-uniform drying behavior. This variability can be attributed to the slower and indirect heat transfer mechanism of conventional ovens, which primarily rely on convective heat transfer from the surrounding air. The thermal inertia and longer heat-up time in oven drying limit its capacity to initiate rapid moisture removal during early drying phases, particularly at lower temperatures (Kim et al., 2021; Akpınar, 2010).

3.2.3 Mathematical Modeling of Drying Behaviour

The experimental drying behavior of calamansi slices under different temperatures and drying methods was evaluated using five established thin-layer drying models: Newton, Page, Modified Page, Henderson and Pabis, and Midilli. Model fitting was assessed through the coefficient of determination (R^2), root mean square error (RMSE), and reduced chi-square (χ^2) as tabulated in Table 3. A model was considered suitable when it demonstrated high R^2 values (close to 1) and minimal RMSE and χ^2 values.

Among the evaluated models, the Midilli model exhibited the highest predictive performance, particularly under infrared (IR) drying conditions at 60 °C and 70 °C, and under oven drying at 80 °C, with R^2 values exceeding 0.9990. This model's inclusion of both exponential and linear terms allows it to effectively capture both the initial rapid drying

phase and the subsequent falling-rate period, where moisture diffusion becomes dominant. These findings align with prior studies highlighting the Midilli model's robustness across varying food matrices and drying conditions (Ça & Selvi, 2020; Younis et al., 2018).

The Page model also demonstrated strong agreement with experimental data, especially for IR drying at 60 °C and oven drying at 60 °C, achieving $R^2 > 0.9995$ and near-zero residual errors. Its flexible structure proved advantageous in modeling non-linear moisture removal dynamics, particularly in mid-range temperatures. This is consistent with its widespread application in modelling fruit and vegetable dehydration processes (Ampah et al., 2022).

The Newton and Modified Page models showed satisfactory performance under specific conditions, particularly IR drying at 50 °C, with R^2 values up to 0.9986. However, their predictive capacity declined at elevated temperatures, likely due to their inability to capture the complexities of internal moisture migration and structural shrinkage occurring in advanced drying stages. The Henderson and Pabis model, although less accurate overall, maintained moderate fit with R^2 values between 0.97 and 0.98, particularly under IR drying. Its comparatively simple formulation may have limited its capacity to reflect the full range of drying kinetics, especially in the transition from constant to falling-rate periods.

The Midilli model emerged as the most appropriate model for describing the drying kinetics of calamansi slices across both drying methods and temperature ranges. Its superior adaptability and consistency highlight its suitability for process modelling and optimization in drying operations. The Page model served as a reliable secondary model, particularly under moderate drying conditions. Conversely, the Newton, Modified Page, and Henderson and Pabis models were limited in scope, with their performance confined to specific drying conditions.

Table 3. Mathematical drying models and statistical values for dried calamansi.

Model Name	Drying Method	Drying Temperature	a	b	k	n	RMSE	X2	R2
Newton	IR Dryer	50°C	–	–	0.0023	–	0.0001	0.0002	0.9889
		60°C	–	–	0.0044	–	0.0017	0.0036	0.9875
		70°C	–	–	0.0085	–	0.0101	0.0214	0.9908
		80°C	–	–	0.0150	–	0.0146	0.0315	0.9885
	Oven	50°C	–	–	0.0009	–	0.0000	0.0000	0.9986
		60°C	–	–	0.0008	–	0.0000	0.0000	0.9979
		70°C	–	–	0.0016	–	0.0000	0.0000	0.9942
		80°C	–	–	0.0020	–	0.0001	0.0001	0.9901
Page	IR Dryer	50°C	–	–	0.0002	1.4899	0.0000	0.0000	0.9958
		60°C	–	–	0.0000	2.3208	0.0001	0.0002	0.9995
		70°C	–	–	0.0000	2.7144	0.0007	0.0016	0.9996
		80°C	–	–	0.0000	2.7013	0.0005	0.0013	0.9996
	Oven	50°C	–	–	0.0001	1.4899	0.0000	0.0000	0.9995
		60°C	–	–	0.0001	1.4899	0.0000	0.0000	0.9998
		70°C	–	–	0.0004	1.2846	0.0000	0.0000	0.9974
		80°C	–	–	0.0000	2.3208	0.0001	0.0003	0.9996
Modified Page	IR Dryer	50°C	–	–	0.0038	1.4906	0.0000	0.0000	0.9958
		60°C	–	–	0.0072	2.2896	0.0001	0.0002	0.9991
		70°C	–	–	0.0103	3.1205	0.0006	0.0013	0.9997
		80°C	–	–	0.0147	3.0565	0.0004	0.0009	0.9997
	Oven	50°C	–	–	0.0009	1.0039	0.0000	0.0000	0.9986
		60°C	–	–	0.0008	1.0093	0.0000	0.0000	0.9980
		70°C	–	–	0.0024	1.2846	0.0000	0.0000	0.9974
		80°C	–	–	0.0032	1.4111	0.0000	0.0000	0.9950
Henderson and Pabis	IR Dryer	50°C	1.0250	–	0.0026	–	0.0001	0.0001	0.9902
		60°C	1.0868	–	0.0054	–	0.0012	0.0027	0.9899
		70°C	1.1709	–	0.0105	–	0.0079	0.0178	0.9930
		80°C	1.0000	–	0.0150	–	0.0146	0.0341	0.9885
	Oven	50°C	1.0000	–	0.0009	–	0.0000	0.0000	0.9986
		60°C	1.0006	–	0.0008	–	0.0000	0.0000	0.9979
		70°C	1.0127	–	0.0017	–	0.0000	0.0000	0.9948
		80°C	1.0175	–	0.0022	–	0.0000	0.0001	0.9909
Midilli	IR Dryer	50°C	1.0111	0.0000	0.0000	2.7248	0.0005	0.0011	0.9992
		60°C	1.0111	0.0000	0.0000	2.7248	0.0004	0.0010	0.9997
		70°C	0.9889	0.0000	0.0000	2.7099	0.0007	0.0019	0.9996
		80°C	0.9970	0.0000	0.0000	2.7005	0.0005	0.0015	0.9996
	Oven	50°C	1.0111	0.0000	0.0000	2.7248	0.0009	0.0020	0.9929
		60°C	1.0111	0.0000	0.0000	2.7248	0.0012	0.0024	0.9924
		70°C	1.0111	0.0000	0.0000	2.7248	0.0009	0.0020	0.9942
		80°C	1.0111	0.0000	0.0000	2.7248	0.0004	0.0010	0.9990

Similarly in oven drying, five widely used thin-layer drying models were fitted to the experimental moisture ratio (MR) data, and model performance was assessed using R^2 , RMSE, and χ^2 as tabulated in Table 3. The Newton, Page, Modified Page, and Henderson & Pabis models showed high accuracy in oven-drying applications, particularly at 50–60 °C. The Newton and Modified Page models achieved R^2 values of 0.9986 with zero RMSE and χ^2 under those conditions.

The Midilli model, however, demonstrated superior flexibility across both IR and high-temperature oven settings. It showed optimal fit at 60 °C in IR drying and 80 °C in oven drying, with R^2 values exceeding 0.999 and minimal RMSE (0.0004) and χ^2 (0.0010). This is consistent with other studies showing that the Midilli model effectively captures drying kinetics in non-linear, high-energy

environments, especially under IR drying of herbs and citrus materials (Çağatay Selvi & Gatay, 2020; Nasr et al., 2021; Górnicki et al., 2020). These results confirm that while simpler models may suffice under lower-temperature convection drying, the Midilli model is most appropriate for predicting the complex behavior of Calamansi drying under variable thermal conditions.

3.3. Effective Moisture Diffusivity (D_{eff})

Table 4 presents the effective moisture diffusivity (D_{eff}) values of Calamansi slices dried at 50 °C to 80 °C. The values of D_{eff} are critical for understanding the mass transfer characteristics during drying, reflecting how efficiently moisture migrates from the interior to the surface of the product.

Table 4. Effective moisture diffusivity of calamansi slice under IR & oven drying at different temperatures.

Type of Dryer	Drying Temperature	Effective Moisture Diffusivity ($\text{m}^2\cdot\text{s}^{-1}$)
IR Dryer	50 °C	1.45×10^{-8}
	60 °C	2.52×10^{-8}
	70 °C	3.31×10^{-8}
	80 °C	5.05×10^{-8}
Oven	50 °C	0.35×10^{-8}
	60 °C	0.35×10^{-8}
	70 °C	1.00×10^{-8}
	80 °C	1.38×10^{-8}

The IR dryer demonstrated significantly higher D_{eff} values than the oven at all temperatures. At 80 °C, IR drying achieved the highest of $5.05 \times 10^{-8} \text{ m}^2/\text{s}$, compared to only $1.38 \times 10^{-8} \text{ m}^2/\text{s}$ for oven drying. This difference underscores the greater drying efficiency of IR drying, attributed to its direct radiation heating mechanism, which provides rapid surface heating and volumetric moisture transport. The difference is consistent with the steeper MR gradients and shorter drying times observed during IR drying. In contrast, the oven relies solely on convective heat transfer, which results in slower internal water diffusion and lower

D_{eff} values (Abdullah et al., 2022; Wang et al., 2021).

D_{eff} increased with temperature for both methods. For IR drying, it rose from $1.45 \times 10^{-8} \text{ m}^2/\text{s}$ at 50 °C to $5.05 \times 10^{-8} \text{ m}^2/\text{s}$ at 80 °C. For oven drying, it increased from 0.35×10^{-8} to $1.38 \times 10^{-8} \text{ m}^2/\text{s}$. Higher temperature increases the vapour-pressure driving force and molecular mobility, thereby promoting internal moisture migration (Kim et al., 2021; Younis et al., 2018). These findings show faster apparent moisture transport under IR drying.

3.4. Shrinkage Effects

Figure 4 presents the shrinkage ratios of calamansi slices subjected to IR and oven drying at temperatures ranging from 50 to 80 °C. The IR-dried samples exhibited higher shrinkage ratios (approximately 0.85–0.865) than the oven-dried samples (approximately 0.77–0.84) across all temperatures. This greater shrinkage may be associated with the faster heating and moisture removal achieved during IR drying, which intensifies moisture gradients and promote the collapse of the cellular structure (Talebzadeh et al., 2022).

For both drying methods, the shrinkage ratio generally increased as the drying temperature increased from 50 to 70 °C. However, a slight reduction was observed for oven drying at 80 °C, possibly due to surface hardening and the formation of a rigid outer layer that restricted further structural contraction (Thuwapanichayanan et al., 2011). In contrast, the shrinkage ratio of IR-dried samples continued to increase slightly at 80 °C, indicating greater structural deformation under the investigated conditions.

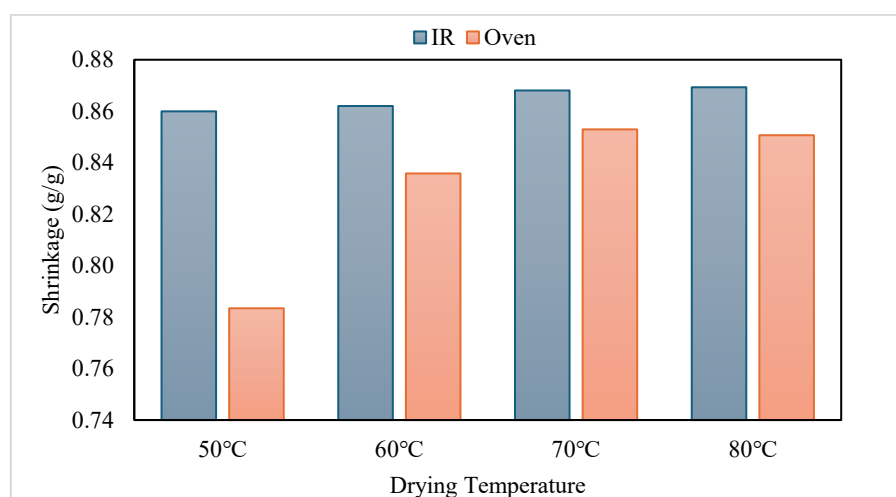


Figure 4. The shrinkage ratio (g/g) of calamansi slices subjected to infrared (IR) and conventional oven drying

4. Conclusion

This study comprehensively evaluated the drying kinetics and physical properties of Calamansi slices subjected to infrared (IR) and oven drying at temperatures ranging from 50 °C to 80 °C. The findings highlight the significant impact of drying method and temperature on drying rate, moisture removal efficiency, and structural changes. IR drying reached the defined endpoint more rapidly and produced higher D_{eff} values than oven drying under the investigated conditions. The Midilli model nevertheless demonstrated high flexibility across IR and high temperature oven drying, achieving $R^2 \geq 0.999$ at IR drying at 60 °C and oven drying at 80 °C. The increase in effective moisture diffusivity with rising temperature and under IR drying conditions was attributed to enhanced vapour-pressure gradients and the

radiative heat transfer mechanism of IR drying. Future investigations should focus on the effects of these drying methods on the nutritional, chemical, and sensory attributes of Calamansi. Such studies would complement the current findings and support the development of optimized, value-added products using sustainable drying technologies.

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