Drying Kinetics and Quality of Grapes (*Vitis Vinifera* L. Cv. Alphonse Lavallée) : Needle Micro-perforation vs. Alkaline Treatment

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INTRODUCTION & AIM

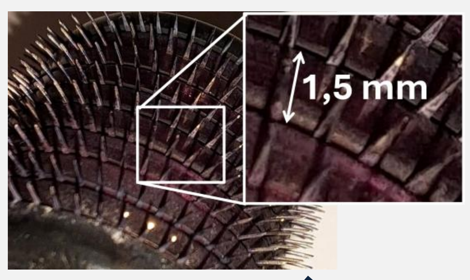
Grapes (*Vitis vinifera L.*) are rich in bioactive compounds such as polyphenols, flavonoids, and anthocyanins, which provide strong antioxidant and health-promoting effects. Kavacık grape, a geographically indicated variety cultivated in İzmir, Turkey, is known for its dark color, thick skin, and high phenolic content. Due to their high moisture content, grapes are highly perishable and require preservation methods such as hot air (convective) drying, which removes moisture through heated airflow and effectively extends shelf-life. However, this method is time- and energy-consuming. Therefore, pretreatments are applied to enhance mass transfer and drying efficiency. Conventional chemical pretreatments like alkaline dipping are effective but raise environmental and safety concerns. Needle micro-perforation offers a promising physical alternative by creating micro-pores on the grape skin, facilitating moisture removal and reducing drying time. To analyze and interpret drying behavior, kinetic modeling is used to describe moisture transfer mechanisms and estimate effective diffusivity. **This study investigates the effects of needle micro-perforation on the convective drying kinetics and quality of Kavacık grapes at different needle lengths (0.5, 1.0, and 1.5 mm) and temperatures (60, 70, and 80 °C), compared with conventional alkaline dipping.**

METHOD

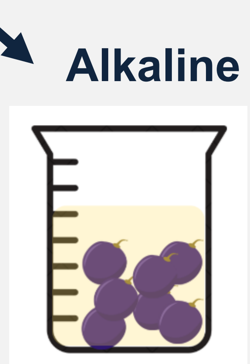
Kavacık Grape

Needle Micro-perforation (MG)

Needle Lengths
0.5 mm
1.0 mm
1.5 mm



Alkaline Dipping (DG)

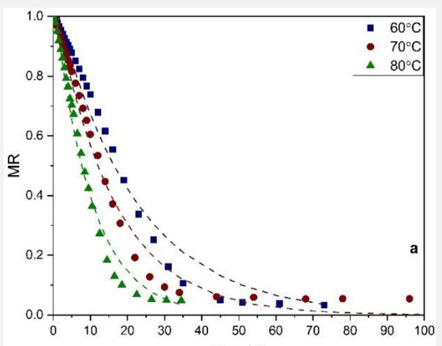


K_2CO_3 (5%)
Olive oil (1-2%)

60 °C
70 °C
80 °C

Convective Drying

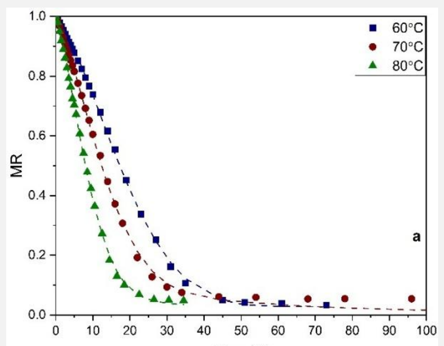
Modelling by Fick's 2[nd] Law of Diffusion



Fickian Diffusion

$$MR_t = \frac{6}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{(2n-1)^2}\,exp\left(-\frac{(2n-1)^2\pi^2 D_{eff}}{4R^2}t\right)$$

Modelling by Fractional Calculus



Non-Fickian Diffusion

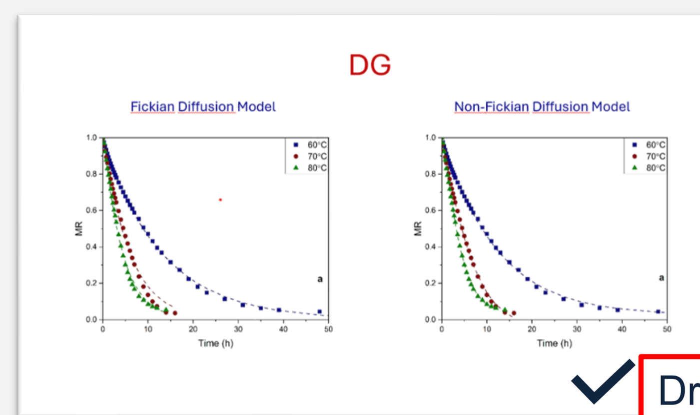
$$MR_t = \frac{6}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{(2n-1)^2}E_a\left(-\frac{(2n-1)^2\pi^2 D_{eff}}{4R^2}t^{\alpha}\right)$$

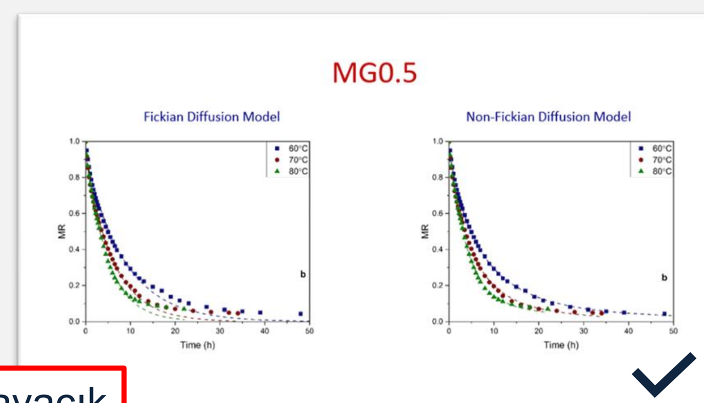
Dried Grape

Analyzes
- Water Activity
- Rehydration Ratio
- pH & Titratable Acidity
- Color
- Shrinkage Ratio

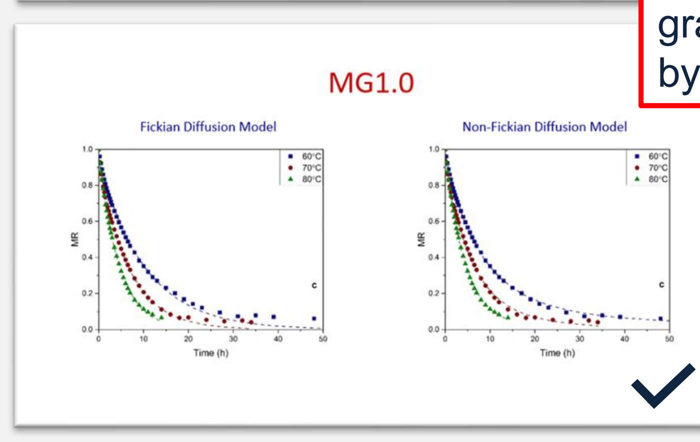
RESULTS & DISCUSSION

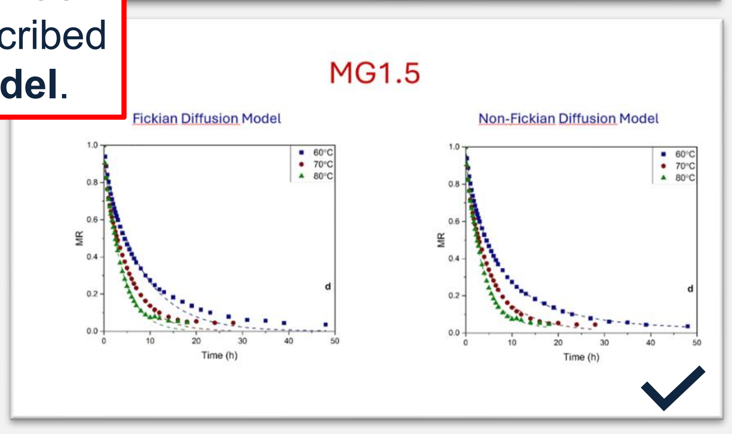
Drying Curves of Grapes





Drying behavior of Kavacık grapes was better described by the **Non-Fickian model**.





Fickian Diffusion Model

	D_{eff} (m^2/s ×10^{-10})			
	DG	MG0.5	MG1.0	MG1.5
60°C	3.38 ± 0.54^{Bb}	5.10 ± 0.33^{ABb}	4.32 ± 0.24^{ABb}	5.52 ± 1.25^{Ab}
70°C	7.62 ± 0.77^{ABa}	7.15 ± 0.37^{Bab}	6.67 ± 0.54^{Bab}	8.80 ± 0.20^{Aab}
80°C	10.81 ± 2.30^{Aa}	9.21 ± 2.03^{Aa}	10.03 ± 2.67^{Aa}	12.21 ± 2.74^{Aa}

T ↑ , D_{eff} ↑

No significant differences in D_{eff} of DG & MG

Non-Fickian Diffusion Model

	D_{eff} (m^2/s ×10^{-10})			
	DG	MG0.5	MG1.0	MG1.5
60°C	3.45 ± 1.29^{Ab}	7.10 ± 0.20^{Ab}	6.09 ± 2.49^{Aa}	7.44 ± 1.45^{Aa}
70°C	5.20 ± 2.70^{Ab}	9.08 ± 1.63^{Aab}	6.46 ± 2.72^{Aa}	9.28 ± 1.64^{Aa}
80°C	16.11 ± 5.44^{Aa}	14.23 ± 4.47^{Aa}	10.34 ± 5.17^{Aa}	12.73 ± 3.25^{Aa}

$\alpha > 1$ for DG → Super-diffusion

$\alpha > 1$ for MG → Sub-diffusion

Physico-chemical Properties of Grape

T ↑

a_w : significant differences in DG

RR : no significant differences

pH : no significant differences (except DG)

TA : significant differences in all samples (except MG0.5)

ΔE : no significant differences

SR : significant differences MG0.5 & MG1.0

Temperature	a_w			
	DG	MG0.5	MG1.0	MG1.5
60°C	0.44 ± 0.05^{Ab}	0.40 ± 0.01^{Aa}	0.47 ± 0.08^{Aa}	0.46 ± 0.04^{Aa}
70°C	0.60 ± 0.05^{Aa}	0.39 ± 0.02^{Ba}	0.52 ± 0.08^{ABa}	0.46 ± 0.05^{Ba}
80°C	0.43 ± 0.01^{ABb}	0.38 ± 0.04^{Ba}	0.41 ± 0.01^{ABa}	0.45 ± 0.03^{Aa}
	RR			
60°C	1.29 ± 0.08^{Ba}	1.89 ± 0.15^{Aa}	2.04 ± 0.10^{Aa}	1.92 ± 0.20^{Aa}
70°C	1.28 ± 0.09^{Ba}	2.08 ± 0.06^{Aa}	1.96 ± 0.10^{Aa}	1.97 ± 0.05^{Aa}
80°C	1.35 ± 0.07^{Ba}	2.04 ± 0.20^{Aa}	2.08 ± 0.08^{Aa}	2.03 ± 0.11^{Aa}
	pH			
60°C	4.33 ± 0.02^{Ab}	4.40 ± 0.14^{Aa}	4.32 ± 0.09^{Aa}	4.42 ± 0.04^{Aa}
70°C	4.43 ± 0.08^{Aab}	4.22 ± 0.13^{Aa}	4.40 ± 0.13^{Aa}	4.34 ± 0.11^{Aa}
80°C	4.47 ± 0.04^{Aa}	4.34 ± 0.08^{ABa}	4.25 ± 0.08^{Ba}	4.39 ± 0.05^{ABa}
	TA			
60°C	0.70 ± 0.08^{ABab}	1.02 ± 0.30^{Aa}	0.94 ± 0.09^{ABab}	0.59 ± 0.08^{Bb}
70°C	0.64 ± 0.06^{Bb}	1.14 ± 0.26^{Aa}	0.85 ± 0.10^{ABb}	0.88 ± 0.13^{ABab}
80°C	0.83 ± 0.04^{Aa}	0.96 ± 0.41^{Aa}	1.13 ± 0.08^{Aa}	0.96 ± 0.19^{Aa}
	ΔE			
60°C	5.72 ± 0.64^{Aa}	4.20 ± 2.29^{Aa}	3.32 ± 2.00^{Aa}	6.95 ± 2.43^{Aa}
70°C	3.61 ± 2.20^{Aa}	2.95 ± 1.71^{Aa}	3.84 ± 0.38^{Aa}	3.23 ± 1.70^{Aa}
80°C	5.44 ± 1.20^{Aa}	5.16 ± 1.28^{Aa}	3.31 ± 1.68^{Aa}	6.07 ± 0.54^{Aa}
	SR			
60°C	0.83 ± 0.10^{Aa}	0.83 ± 0.06^{Aab}	0.86 ± 0.01^{Ab}	0.86 ± 0.01^{Aa}
70°C	0.81 ± 0.03^{ABa}	0.76 ± 0.03^{Bb}	0.86 ± 0.01^{Ab}	0.80 ± 0.02^{ABa}
80°C	1.00 ± 0.18^{Aa}	1.00 ± 0.13^{Aa}	1.02 ±0.11^{Aa}	0.98 ± 0.19^{Aa}

*Means ±standard deviation within a row followed by different capital letters and within a corresponding section's column followed by different small letters are significantly different (P< 0.05).

CONCLUSION

Needle micro-perforation proved to an efficient alternative to alkaline dipping at **lower temperatures**, significantly **improving moisture diffusivity** while **maintaining the physico-chemical properties of the grapes.**