Comparative Analysis of Drying Techniques for Custard Apple Pulp: Hot Air, Vacuum, and Microwave-Assisted Methods

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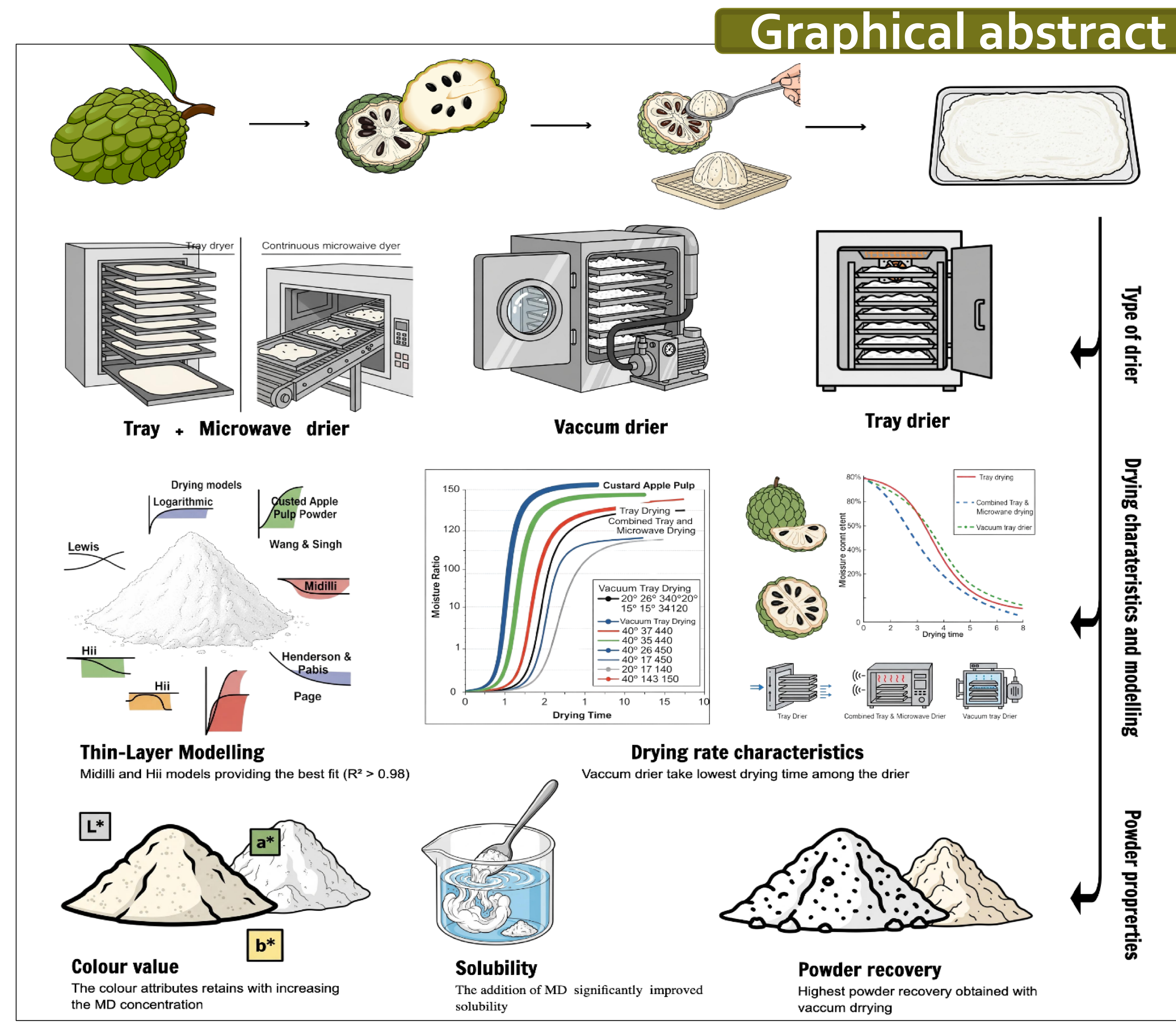
Graphical abstract



Introduction

- **Custard apple** (*Annona squamosa L.*) is a highly valued tropical fruit known for its sweet, creamy pulp, distinctive aroma, and rich nutritional profile.
- Despite its desirability, the fruit is extremely perishable, with a shelf life of only 3–4 days at ambient temperatures, leading to rapid postharvest deterioration like softening and microbial spoilage.
- This short shelf life significantly restricts its commercial use and distribution.
- **Drying** is a crucial and widely adopted preservation technique that extends the shelf life of perishable fruits by reducing water activity, facilitating storage, and transport.
- However, the choice of drying method is critical, as traditional methods like **hot-air drying** (e.g., tray drying) can compromise quality by degrading heat-sensitive nutrients, while advanced methods like **vacuum drying** or **microwave drying** have drawbacks such as high cost or non-uniform heating.

Objectives

- To compare the efficacy of three distinct drying techniques—tray drying (TD), vacuum drying (VD), and dual tray–microwave drying (TMD)—for Custard Apple Pulp (CAP) preservation.
- Evaluate key quality parameters of the dried CAP product, including solubility, recovery percentage, and color, which are essential metrics for consumer acceptance and industrial application.

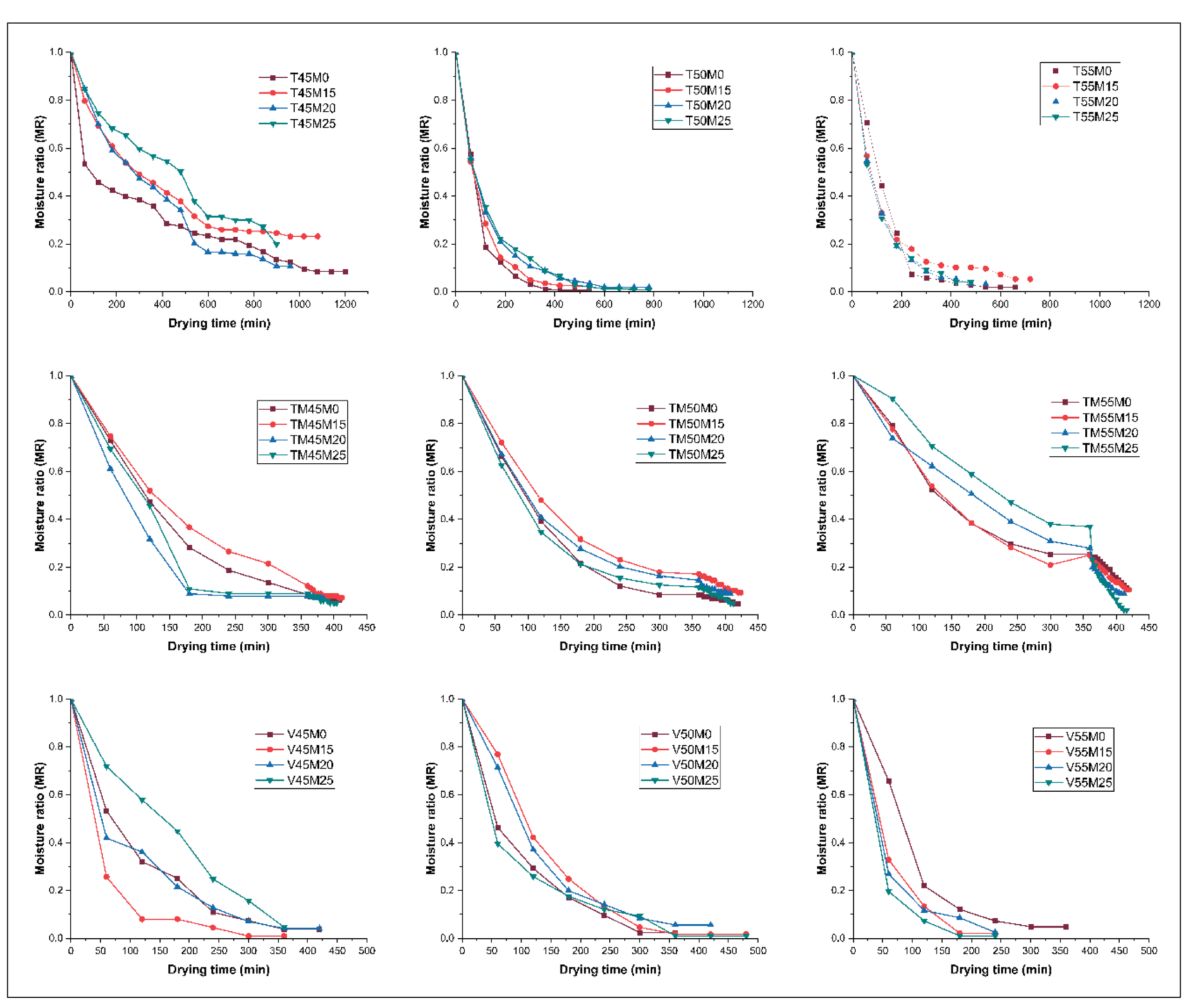


Figure: Experimental drying rate curve of custard apple

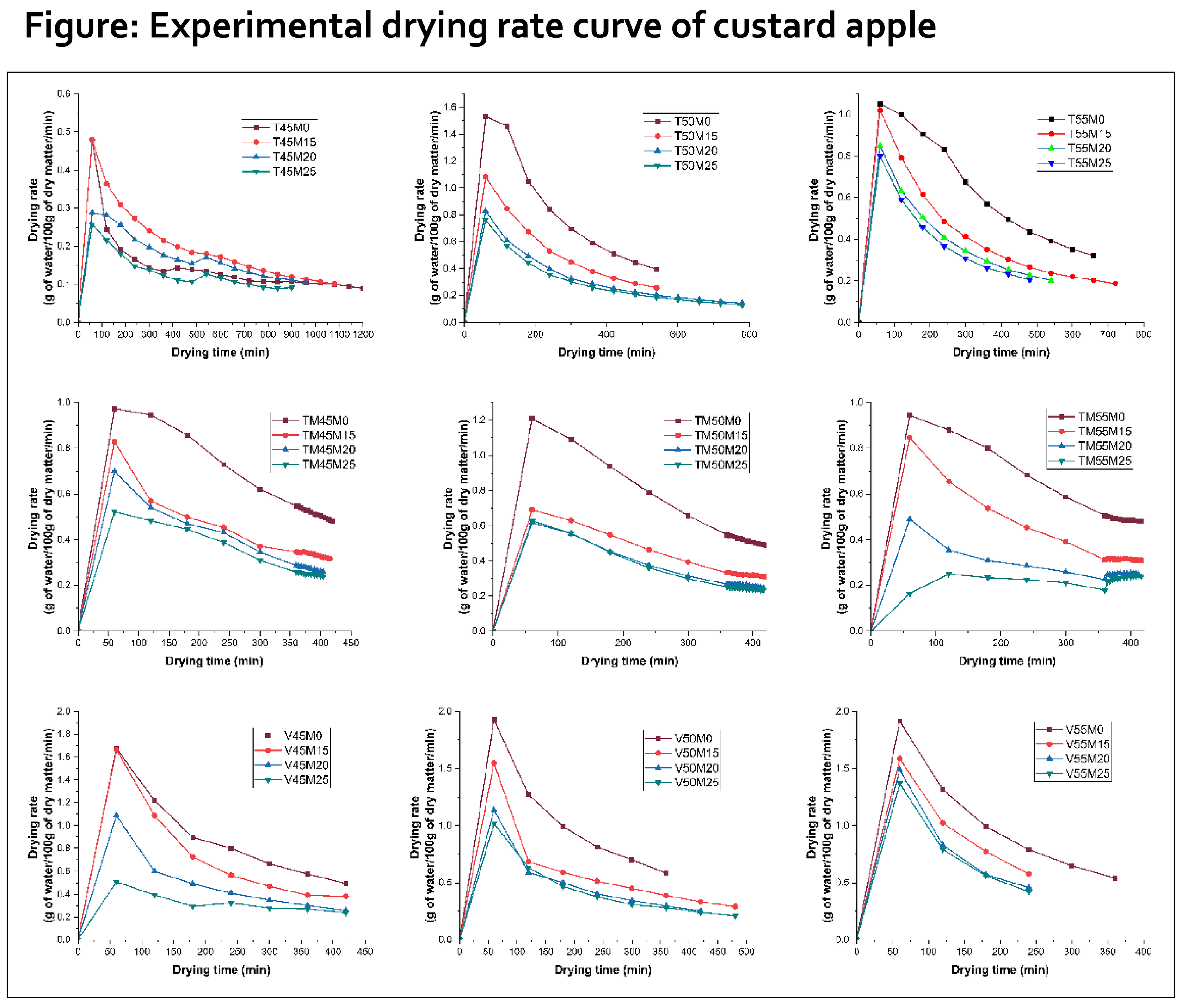
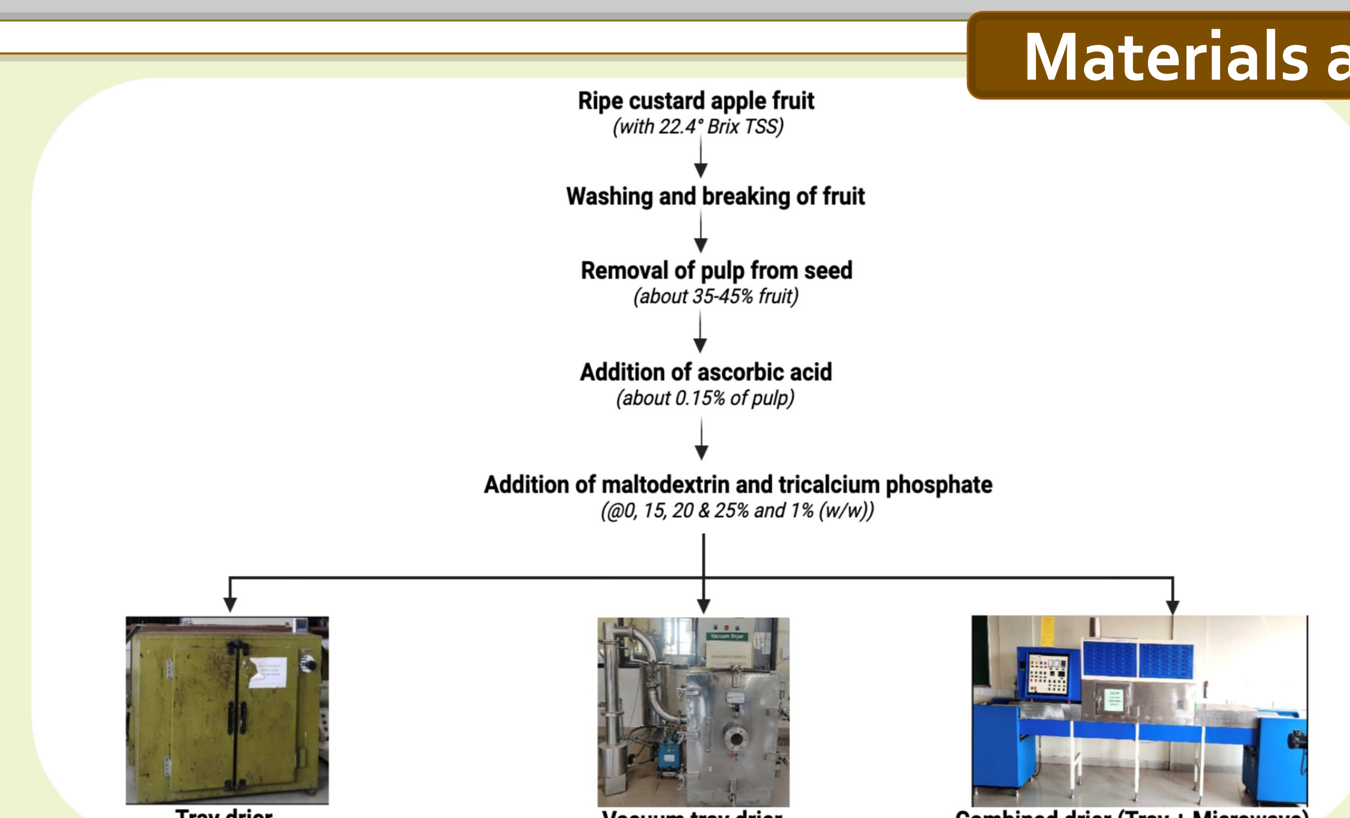


Figure: Moisture ratio vs drying time curve of custard apple

Materials and Methods



Model name	Model equation	References
Lewis	$MR = \exp(-kt)$	Ertekin & Yaldiz (2004)
Logarithmic	$MR = a\exp(-kt) + c$	Yaldiz & Ertekin (2002)
Wang & Singh	$MR = 1 + at + bt^2$	Wang & Singh (1978)
Midilli	$MR = a\exp(-kt^n) + bt$	Midilli et al. (2002)
Hii	$MR = a\exp(-kt^n) + c\exp(-gt^n)$	Hii et al. (2009)
Henderson & Pabis	$MR = a\exp(-kt)$	Henderson & Pabis (1961)
Page	$MR = \exp(-kt^n)$	Page (1949)

Discussion

- **Vacuum Drying (VD) achieved the Shortest Drying Times:** VD was the fastest method, beating tray and microwave drying, because the vacuum's reduced boiling point accelerated moisture removal.
- **Maltodextrin (MD) Addition Improved Drying Characteristics:** Adding maltodextrin (MD) as a carrier agent improved drying efficiency across all methods by reducing total drying time and increasing powder recovery.
- **Midilli and Hii Models Provided the Best Fit for Drying Kinetics:** The Midilli model best described the drying kinetics for vacuum drying, while the Hii model provided the best fit for tray drying and tray-microwave drying.
- **Vacuum Drying with 20-25% MD Yielded the Highest Powder Recovery:** Vacuum drying combined with 20-25% MD achieved the maximum powder recovery (up to 50.25%), significantly outperforming the other drying methods.

Conclusions

- This study demonstrated that vacuum drying with 20-25% maltodextrin was the most efficient method, achieving the shortest drying times,
- Highest powder recovery (up to 50.25%), and superior solubility and color retention.
- The Midilli and Hii models effectively predicted the drying kinetics.