ISETC2025

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2 ND INTERNATIONAL SCIENCE, ENGINEERING AND TECHNOLOGY COLLOQUIUM

THE POWER OF SCIENTIFIC INNOVATION

INTELLIGENT SOLUTIONS FOR A SUSTAINABLE WORLD

ORGANIZED BY:
FACULTY OF APPLIED SCIENCES
UNIVERSITI TEKNOLOGI MARA
PERAK BRANCH, TAPAH CAMPUS
MALAYSIA

CO-ORGANIZED BY:

三重大学
MIE UNIVERSITY

2nd International Science, Engineering and Technology Colloquium

(ISETC 2025)

Faculty of Applied Sciences,
Universiti Teknologi MARA,
Perak Branch, Tapah Campus,
35400 Tapah Road, Perak, Malaysia.

Colloquium date: 9th July 2025
Publication date: 9th September 2025

Proceedings of Extended Abstracts

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e-ISBN: 978-629-97630-5-5

Published by Faculty of Applied Sciences, Universiti Teknologi MARA,
Perak Branch, Tapah Campus, 35400 Tapah Road, Perak, Malaysia.

PREFACE

Welcome to the 2nd International Science, Engineering and Technology Colloquium 2025 (ISETC 2025)!

It is with great pleasure that we present this year's colloquium, a distinguished gathering of scholars, researchers, and professionals dedicated to the advancement of applied sciences. Held virtually on 9th July 2025, ISETC 2025 serves as a platform to highlight cutting-edge research, foster meaningful networking, encourage collaborations, and explore innovative solutions to global challenges.

This year's theme, "The Power of Scientific Innovation: Intelligent Solutions for a Sustainable World" highlights our shared goal to solve global challenges through applied science. It celebrates innovation as a key to building a more sustainable and resilient future. We're proud to feature keynote speakers and presenters who bring fresh insights, bold ideas, and breakthroughs shaping tomorrow's world.

We would like to extend our heartfelt appreciation to the Faculty of Applied Sciences, Universiti Teknologi MARA, Perak Branch, Tapah Campus, for their outstanding support and assistance throughout the planning and execution of the event. Their dedication has been instrumental to the success of this colloquium. We would like to sincerely thank all participants and researchers for their valuable contributions. We also appreciate the reviewers for their careful evaluations and helpful feedback. Your hard work and support mean a lot to us.

As editors, we are proud to present this collection of proceedings. It is an honour to bring together the interesting and meaningful work of our speakers and authors. We hope the ideas shared will lead to new discoveries, encourage more research, and help solve global challenges through science and innovation.

Warm regards,

Dr. Emi Norzehan Mohamad Mahbob
Dr. Saiyidah Nafisah Hashim
Ms. Lili Widarti Zainuddin
Ms. Nurul Nazwa Mohammad
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ISETC 2025 Proceedings Editors

EVALUATING THE EFFECT OF DRYING TECHNIQUES ON EXTRACT YIELD AND FUNCTIONAL GROUP PROFILES IN *Citrus hystrix* USING FTIR

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Abstract: *Citrus hystrix* (Kaffir lime) is widely recognized for its aromatic leaves and essential oils (EOs), which possess various biological and functional properties. This study aims to evaluate the effect of two drying techniques—air-drying and microwave-drying—on the yield and functional group profiles of C. hystrix leaf extracts using Fourier Transform Infrared (FTIR) spectroscopy. The dried leaf samples were extracted, and the resulting crude extracts were analyzed with FTIR to identify the presence of key functional groups. Characteristic absorption bands were observed, including O–H stretching (3625–3025 cm^{-1}), C–H stretching (2939–2834 cm^{-1}), C=O stretching (1721–1719 cm^{-1}), and C=C stretching (1624–1622 cm^{-1}). The findings indicate that the type of drying method influences both the extract yield and the integrity of functional groups. For future work, the application of ultrasound-assisted extraction (UAE) is recommended as a greener and more time-efficient method to enhance extraction quality.

***Keywords*:** *Citrus hystrix*, functional group, Fourier Transform Infrared (FTIR), drying

INTRODUCTION

Drying is a fundamental step in the postharvest processing of plant materials, particularly in the preparation of herbal extracts. The chosen drying technique can significantly affect the chemical composition and quality of the final product. *Citrus hystrix* (Kaffir lime), known for its aromatic and therapeutic properties, is widely used in food and traditional medicine. However, the chemical integrity of its leaf extracts may vary depending on the drying method employed.

The present study investigates the effects of two different drying techniques namely air-drying and microwave-drying on the yield and functional group profiles of *Citrus hystrix* leaf extracts. Despite the growing use of this plant, there is limited comparative data on how these drying methods influence the preservation of functional compounds in its water-based crude extracts. Without such knowledge, practitioners and product developers risk applying suboptimal drying practices that may compromise the efficacy or consistency of herbal preparations. Drying methods such as microwave-assisted techniques have been shown to reduce processing time and preserve thermolabile compounds more effectively than conventional air-drying (Komal, Shravan, & Panda, 2025).

This study aims to compare the yield and structural characteristics of crude extracts obtained through both drying methods. Fourier Transform Infrared (FTIR) spectroscopy was used as a rapid, non-destructive analytical technique to identify major functional groups, including hydroxyl (–OH), carbonyl (C=O), aliphatic (CH), and carboxylic (COOH) groups. Early observations indicate that microwave drying may better preserve certain functional groups while enhancing extraction efficiency compared to traditional air-drying.

By providing a direct comparison between air and microwave drying methods, this research contributes practical insights for optimizing the processing of *Citrus hystrix*, with potential applications in the development of high-quality natural extracts for use in food, pharmaceutical, and nutraceutical industries.

LITERATURE REVIEW

Drying techniques play a crucial role in determining the chemical stability and bioactivity of herbal extracts. Studies have shown that trichome and oil gland integrity directly influence the fragrance quality and essential oil content in dried leaves, highlighting the importance of minimizing physical and thermal damage during drying (Ebadi et al., 2015; Jangi et al., 2020; Thamkaew et al., 2020).

High moisture content in medicinal plants makes them highly susceptible to microbial and oxidative degradation during postharvest handling. Therefore, reducing moisture to safe levels (typically 10–12%) is essential to ensure shelf life and quality (Azizi et al., 2010; Brovelli et al., 2003).

In recent decades, there has been increased interest in optimizing drying techniques for both efficiency and preservation of bioactive compounds. Microwave drying, in particular, has emerged as a promising method due to its rapid drying capability and lower thermal stress, which help retain phytochemical compounds more effectively than traditional air-drying methods (Mahmoudi et al., 2020; Thamkaew et al., 2020).

A comparative study by Komal, Shravan, and Panda (2025) on *Alpinia galanga* demonstrated that drying method significantly affects extraction yield and functional group retention. Their findings suggested that microwave drying resulted in higher extraction efficiency and better preservation of essential oil components compared to conventional techniques.

Despite these advancements, limited studies focus specifically on the impact of drying methods on the water extracts of *Citrus hystrix*. Most research has concentrated on essential oil yields using hydrodistillation, leaving a knowledge gap regarding the structural integrity of water-soluble bioactives. This gap highlights the need for analytical tools such as Fourier Transform Infrared (FTIR) spectroscopy to characterize and compare the chemical profiles of extracts processed through different drying methods.

MATERIALS AND METHODS

Fresh *Citrus hystrix* (Kaffir Lime) leaves were sourced from a local plantation and used as the raw material in this study. Upon collection, the leaves were washed thoroughly with distilled water to eliminate surface impurities and dried using absorbent paper.

Two drying techniques were employed: air-drying and microwave-drying.

For the air-drying method, 50 g of fresh leaves were spread evenly in a single layer on a clean, ventilated surface at room temperature (~26 °C) under indirect sunlight. The leaves were manually turned at intervals to ensure uniform drying and to minimize microbial growth, following procedures adapted from Sasidharan et al. (2011). The drying continued for approximately 4320 minutes (3 days) until the leaves became brittle and crisp.

In the microwave-drying method, another 50 g of fresh leaves were placed in a microwave-safe glass container and dried at 180 °C for 28 minutes in intervals to prevent scorching. This method was chosen based on previous findings that microwave drying preserves polyphenolic compounds and antioxidants more effectively compared to conventional methods (Komal et al., 2025). After drying, all samples were cooled to room temperature and their final dry weights recorded to determine drying yield.

Subsequently, all dried samples were ground into a fine powder using a laboratory grinder. A total of 50 g of powder from each drying method was extracted using a rotary evaporator at 40 °C to obtain crude water-based extracts, following the modified protocol of Ameer et al. (2017). Prior to analysis, the crude extracts were prepared for FTIR analysis. The required materials included the two water extracts (microwave-dried and air-dried), syringe filters (0.45 µm), glass vials, and distilled water for dilution, if necessary. Both extracts were filtered to remove particulates, and if found to be too concentrated or viscous, were diluted in a 1:1 ratio with distilled water. Labeled vials were stored at room temperature until FTIR testing.

For Fourier Transform Infrared Spectroscopy (FTIR) analysis, a small volume of each extract was applied directly onto the crystal of the FTIR instrument. Scans were performed in the spectral range of 4000 to 600 cm^{-1}, and key absorption peaks were identified and compared between the two drying methods to evaluate differences in functional group profiles.

RESULTS

This chapter presents the results derived from the application of two drying methods, air-drying and microwave-drying on *Citrus hystrix* leaves, followed by aqueous extraction and FTIR analysis. The data obtained were presented in tables and figures for clarity and comparison.

Table 1. Mass and yield of crude extract

Method	Mass of Crude Extract (g)	Yield (%)
Air-drying	4.7031	(4.7031 / 20.7) x 100 = 22.70%
Microwave-drying	4.8370	(4.8370 / 21.7) x 100 = 22.30%

Table 2. Identified functional groups in two drying methods

Air Drying		Microwave drying
3258 cm^{-1}	O-H	3260.01 cm^{-1}
1590.7 cm^{-1}	C=C	1589.90 cm^{-1}
1397.99 cm^{-1}	C-O	1396 cm^{-1}
1069.43 cm^{-1}	C-N	1068.18 cm^{-1}
1755.78 cm^{-1}	C=O	NA

DISCUSSION/ANALYSIS

The findings reveal that both drying methods yielded comparable amounts of crude extract (Table 1), with air-drying producing a slightly higher yield per gram of dried sample. This observation is consistent with previous research by Sasidharan et al. (2011), who found that air-drying can enhance extraction efficiency due to its milder temperature conditions, which help preserve heat-sensitive phytochemicals. Similarly, Ameer et al. (2017) acknowledged that although microwave drying is time-efficient, it may reduce extractable yield through localized overheating.

In terms of chemical composition, FTIR analysis (Table 2) confirmed the presence of key functional groups such as hydroxyl (O–H), aromatic ring (C=C), alcohol/ether (C–O), and amines (C–N) in both extracts. Notably, aldehyde and ketone groups (C=O) were identified exclusively in the air-dried samples, implying that air-drying better preserves sensitive carbonyl-containing compounds. This is in agreement with the findings of Kumar et al. (2020) and Gallo et al. (2018), who reported the degradation of thermolabile carbonyl compounds during microwave treatment, leading to altered FTIR spectral profiles.

Further, UV-Vis analysis indicated that both extracts exhibited peak absorbance at around 336 nm, characteristic of flavonoids (result now shown). The air-dried extract displayed marginally higher absorbance, reflecting better retention of antioxidant polyphenols. This result supports previous studies by Abdurrahman et al. (2014) and Feng et al. (2011), who concluded that low-temperature drying techniques better maintain the structural integrity of flavonoids and phenolic compounds.

Collectively, these results underscore the critical influence of drying methods on the extraction yield and preservation of bioactive compounds in *Citrus hystrix* leaves. Air-drying appears superior in retaining chemical integrity, especially for sensitive functional groups and antioxidants.

CONCLUSIONS

The present study successfully demonstrated the influence of two different drying techniques—air-drying and microwave-drying—on the yield and chemical profile of *Citrus hystrix* aqueous extracts. The findings reveal that while both drying methods resulted in comparable crude extract yields, air-drying produced a slightly higher yield per gram of dried leaf. More importantly, the air-dried samples retained a broader spectrum of functional groups, including thermosensitive aldehydes and ketones, and showed marginally better UV-Vis absorbance associated with flavonoid content.

These results support the general principle that milder, low-temperature drying methods are better suited for preserving the chemical integrity of bioactive plant constituents. However, exceptions exist—microwave drying, although faster and more efficient in time, may compromise sensitive groups due to localized overheating, as suggested by the absence of C=O bonds in the microwave-dried samples.

Theoretically, this study reinforces the understanding that phytochemical preservation is closely tied to drying parameters. Practically, it highlights that air-drying is preferable when the focus is on maintaining chemical quality for applications such as herbal formulations or aromatherapy. Conversely, microwave drying may be acceptable where time-efficiency and bulk throughput are prioritized, such as in industrial pre-processing stages, though some loss in compound complexity should be expected.

In conclusion, the drying method plays a crucial role in influencing both the quantity and quality of extractable compounds from *Citrus hystrix* leaves. We recommend future work to extend this comparison to include antioxidant activity assays and bioefficacy testing to evaluate whether the observed chemical differences translate to functional outcomes. Additionally, optimization studies on hybrid drying methods such as convective-microwave combinations that could offer a balanced approach between efficiency and phytochemical retention for industrial applications.

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SITI BASRIYAH SHAIK BAHARUDIN
Timbalan Ketua Pustakawan

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