Comparative Chemical Profiling of Essential Oils of *Elettaria cardamomum* (L.) Maton and *Elettaria ensal* Using GC-MS, FT-IR, and Raman Spectroscopy

D.H. De Zoysa[1], N. Abeyasinghe[1], O.V.D.S.J. Weerasena[2], N. Fernando[2], S.M. Handunnetti[2], S.I.C. Silva[3], H.D.S.M. Perera[1]
[1]Department of Chemistry, University of Colombo, Sri Lanka
[2]Institute of Biochemistry, Molecular Biology and Biotechnology, University of Colombo, Sri Lanka
[3]Department of Export Agriculture, Sri Lanka

Commonwealth Chemistry
Federation of Chemical Sciences Societies

Introduction

The detection of adulteration of true cardamom [*Elettaria cardamomum* (L.) Maton] with powdered wild cardamom (*Elettaria ensal*) *remains* a significant challenge in the global spice trade [1]. Cardamom essential oil (CEO) is a major value-added product of cardamom and its quality is currently evaluated using gas chromatography-mass spectrometry (GC-MS), thin layer chromatography (TLC), and trained panelist evaluations, which are limited by lengthy sample preparation, low sensitivity, and subjective bias[1].

Figure 1: wild cardamom (*Elettaria ensal*)

Figure 2: True cardamom [*Elettaria cardamomum* (L.) Maton]

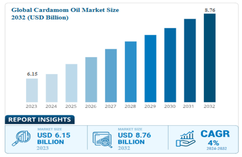


Figure 3: Global cardamom oil market value and its expected growth

Objective

To evaluate Fourier-transform infrared spectroscopy (FT-IR) and Raman spectroscopy as alternative analytical tools for differentiating the essential oils (EOs) of true cardamom (TC) and wild cardamom (WC) validated against GC-MS.

Methodology

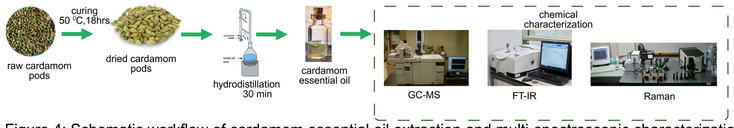


Figure 4: Schematic workflow of cardamom essential oil extraction and multi-spectroscopic characterization

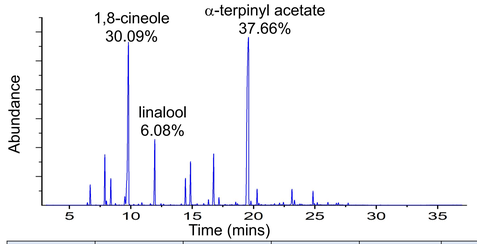
Extraction of CEO: Raw cardamom pods were cured at 50 ˚C for 18 hrs. Ground cardamom were subjected to ultrasound-pretreatment at 50 Hz for 30 min, followed by hydrodistillation for 30 min to obtain the essential oil.

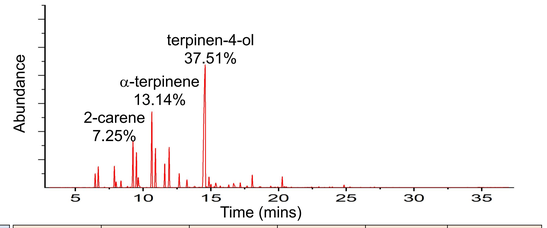
Chemical characterization: The extracted CEO was characterized using GC-MS,FT-IR and Raman spectroscopy, and the resulting spectra were qualitatively compared.

Results

True cardamom essential oil (TCEO) | Wild cardamom essential oil (WCEO)

Gas chromatography- mass spectroscopy (GC-MS)

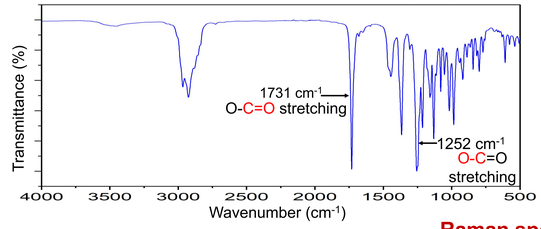


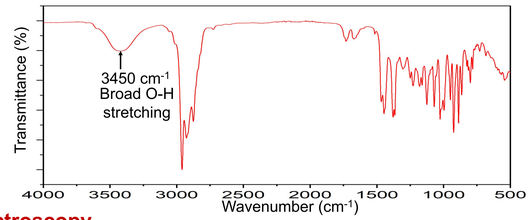


Terpenes (%)	Terpenoid alcohols (%)	Terpenoid esters (%)	Terpenoid aldehydes (%)	Terpenoid ether (%)	Total Compounds (%)
10.44	12.69	43.70	0.97	30.21	98.10

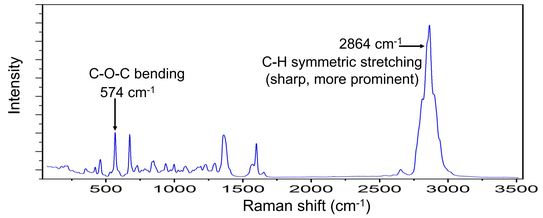
Terpenes (%)	Terpenoid alcohols (%)	Terpenoid esters (%)	Terpenoid aldehydes (%)	Terpenoid ether (%)	Total compounds (%)
33.31	55.57	1.96	1.26	0.00	92.12

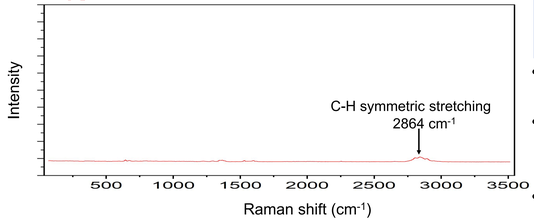
Fourier-transform infrared spectroscopy(FT-IR)





Raman spectroscopy





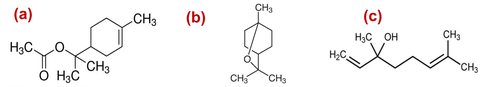


Figure 5: Chemical structures of (a) α-terpinyl acetate (b) 1,8-cineole (c) linalool (d) terpinen-4-ol (e) α-terpinene and (f) 2-carene

Discussion

GC-MS	FT-IR	Raman
TCEO: ester + ether rich (73.9%) Key markers: α-terpinyl acetate & 1,8-cineole	**TCEO:** Sharp ester peaks at 1731 & 1252 cm^{-1} confirm ester bonds.	1,8-cineole-specific peaks at 467–680 cm^{-1} in TCEO.
WCEO: alcohol rich (55.57%) Key marker: terpinen-4-ol	**WCEO:** Broad O-H absorption at 3450 cm^{-1} confirms dominant alcohols.	Dominant C-H stretching at 2864 cm^{-1} confirms ester-rich vs. alcohol-rich profile.

Conclusion

The strong GC-MS and FT-IR spectroscopic agreement reveals Raman as a potential tool for cardamom authentication and adulteration detection in routine quality control.

References

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Acknowledgement

- Funded by National Science Foundation (NSF), Sri Lanka (Grant no. RG/2024/BS/02)
- Research facilities provided by the Department of Chemistry, Faculty of Science, and Institute of Biochemistry, Molecular Biology and Biotechnology, University of Colombo.
- Sample collection supported by Department of Export Agriculture, Sri Lanka