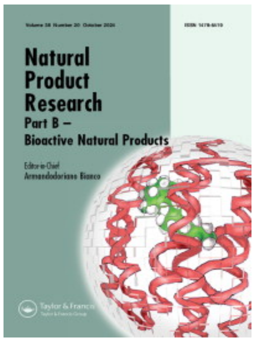

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SHORT COMMUNICATION

Chemodiversity of *Zingiber officinale* Roscoe rhizome essential oil at different drying times

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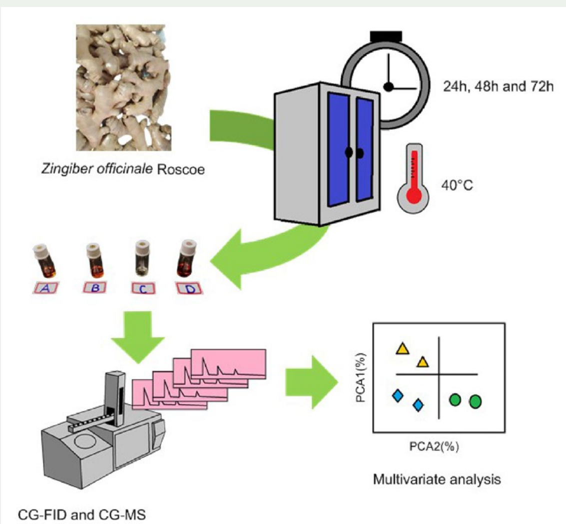
ABSTRACT

Ginger (*Zingiber officinale*), a globally distributed plant, is widely used in the industry for its flavourings, seasonings, and beverages. However, maintaining its quality and volatile components during processing has posed a challenge. This study, therefore, aimed to assess the impact of drying time (24, 48, and 72h) in a circulation oven at 40 °C on the chemical composition and yield of fresh and dried ginger. The essential oils were extracted using the hydrodistillation method, and their chemical analysis was conducted using gas chromatography. The drying time in the oven directly influenced the essential oil yield, with a longer time resulting in a higher yield. We identified 27 compounds in the essential oils, varying their predominance depending on the drying time. The PCA analysis revealed that the drying time can lead to the formation of different chemotypes for ginger, indicating that altering the drying time can yield significantly different chemical profiles.



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1. Introduction

Zingiber officinale Roscoe, popularly known as ginger, is a plant belonging to the Zingiberaceae family, native to Asia, and found in different parts of the world. Ginger rhizome is widely used in fresh and dried forms (Mahboubi 2019; Shahrajabian et al. 2019). When dehydrated, it is used as a condiment and can also be used to extract oleoresin, which is widely used in the food industry. (Bag 2018; Zhang et al. 2022). Another precious product that can be obtained from the ginger rhizome is the essential oil, which has several beneficial properties for health, such as anti-inflammatory, analgesic, antioxidant, antibacterial, antifungal, insecticide, and antitussive effects (Noshirvani et al. 2017; Foko et al. 2018; Munda et al. 2018; Romoli et al. 2022; Abdullahi et al. 2020; Wang et al. 2020; Kalhoro et al. 2022).

Considering the wide use of ginger, it is interesting to develop processing methods that ensure its preservation over time. Due to the high moisture content of the ginger rhizome, an effective dehydration process is essential to ensure its long-term conservation. However, drying the material can cause some losses in the quality of the material, which makes this process a challenge, especially when it comes to the volatile components present in ginger plant material (Baruah et al. 2019; Ghafoor et al. 2020). From this perspective, the drying process influences the chemical composition of ginger essential oil, reducing the percentage of bioactive compounds responsible for properties such as odour, flavour, and biological activity. On the other hand, if the drying process is controlled, it can lead to favourable percentages of bioactive compounds and maintain the properties of ginger or even attribute new ones. (Sasidharan and Menon, 2010; Zagórska et al. 2023; Aabha et al. 2024).

Some studies have addressed the analysis of different drying methods and their influence on the chemical composition of ginger essential oil (Huang et al. 2012; Jayashree et al. 2014; Yu et al. 2022). Furthermore, multivariate analysis can effectively relate the drying method to the composition of essential oils (Dorneles et al. 2019; Wang et al. 2021; Peixoto et al. 2024). However, studies on the influence of ginger drying time are scarce. Thus, this work aimed to analyse the chemical composition of ginger essential oil at different drying times using multivariate analysis.

2. Results and discussions

2.1. Chemical and physical characterisation of ginger essential oils

Table S1 shows the yield, refractive index, density, and colour values for the treatments to obtain essential oil from ginger rhizome. The variation in drying time in a forced circulation oven at 40 °C directly influences the yield of essential oil from ginger rhizome; a longer drying time implies a gain in essential oil yield. This behaviour was already expected, as the water content of the ginger rhizome decreases with increasing drying time.

Regarding the correlation between drying time and the yield of essential oil from the ginger rhizome, the literature is scarce with results on this variable. Research conducted by Jayasundara and Arampath (2021) investigated the extraction efficiency of essential oil from dried ginger rhizome in an oven at 50 °C, a drying temperature similar to that addressed in this study. The rhizomes were harvested at different times after planting and subjected to approximately 96 h of drying. However, no study was carried out on the effect of drying time. In this work, the authors reported that the maximum yield of ginger essential oil occurred with the rhizomes harvested five months after planting, reaching 3.36% and a minimum of 1.61%, with the ginger being different varieties from Sri Lanka.

The experimentally determined refractive indices are similar for the four samples of ginger essential oil. This indicates that the heat treatment does not affect this parameter, except for the oil obtained from the 72-hour treatment, which showed a decreased change in the refractive index. This is possibly due to the chemical composition, which decreases the main compounds in the oil over 72 h (Table S2).

The density varies slightly, except for the ginger sample dried for 24 h, which showed a higher density of 1.08 g mL^{-1}. This greater density can be attributed to a higher concentration of terpenes in the oil. Regarding chemical composition, the compounds present in ginger rhizome essential oils were identified (Table S2) and are by the review carried out by Liu et al. (2019), which lists a wide variety of volatile compounds found in ginger essential oil. Moisture was also determined (Table S2). The values obtained for the 4 treatments are very close. However, the 24-hour treatment differs statistically from the others. The 24-hour drying time cannot remove all the water from the ginger-like at other times. The 48-hour and 72-hour drying times, the ginger loses all its water.

The essential oil from the freshly extracted ginger rhizome (treatment A) contained 17 compounds. The compounds with the most significant predominance in the relative area were *α*-zingiberene (33.29%), *α*-farnesene (17.36%), sesquiphelladrene (12.45%), and geranial (11.49%) (Table S1). In studies conducted by Feng et al. (2018), Sharma, Sing, and Ali (2016), and Osae et al. (2021), *α*-zingiberene was also recognised as the main component of fresh ginger oil, with percentages ranging from 26.00%, 46.71% to 40.62%, respectively.

In treatment B, the ginger rhizome was dried in an oven at 40 °C for 24h, and 18 compounds were identified, as seen in Table S2 and Figure S1. The percentage of oxygenated monoterpenes increased in this drying condition. *α*-zingiberene (5.26%) ceased to be the majority compound, and geranial began to occupy this position with 20.38% relative area.

This phenomenon may have occurred because geranial (bt = 230 °C) has a higher boiling temperature and α-zingiberene (bt = 135 °C), which may result in the loss of this compound during the drying process. In the work by An et al. (2016), a reduction in the number of hydrogenated sesquiterpenes was observed when the ginger rhizome sample was heated to 60 °C. As we can see in Table S2 and Figure S1, this phenomenon occurs when the treatments go through the oven drying process at 40 °C compared to the fresh ginger rhizome. The reduction of hydrogenated sequiterpenes may be because they degrade and lead to the formation of monoterpenes (An et al. 2016). There is a reduction in hydrogenated sesquiterpenes from the fresh method to the others. In the work of Kamal et al. (2023), the same effect occurs from fresh ginger to that dried in the greenhouse. The oxygenated monoterpenes increased from the fresh sample to the sample dried for 24 h and then slightly decreased for the other samples. Aabha et al. (2024) used different drying methods for ginger rhizomes, and the number of oxygenated monoterpenes was always high.

Vaz et al. (2022) found geranial and β-phelladrene as the main constituents in fresh ginger samples. The yield was 0.26%, close to that determined in the present study (Table S1, Figure S1), for the sample dried for 24 h. The chemical profile, similar to the 24h drying time in Table S2, has antibacterial activity confirmed in some studies in the literature (Snuossi et al. 2016; Das et al. 2019; Gunasena et al. 2022).

In the 48-hour sample, 24 compounds were found. In this condition, the main compounds became geranyl acetate (15.29%), geraniol (13.46%), and geranial (11.17%). For the 72-hour sample, 25 compounds were identified. In this drying condition, the composition is also more homogeneous, so the main compounds have very close areas; in this condition, the main compounds are similar to the 48-hour sample, being geranyl acetate (13.27%), geraniol (11.74%) and geranial (9.61%). Unlike what occurs with drying times of 24h and 48h, in the 72h time, there was an increase in the class of hydrogenated sesquiterpene compounds.

Among the compounds that showed more significant predominance in the 48 and 72 h profiles, geranyl acetate, geranial and geraniol stand out. It is important to note that the chemical profile of samples from 48 and 72 h is not similar to others found in the literature for fresh samples. However, Sasidharan et al. (2012) extracted essential oil from the rhizomes of two ginger varieties, Bhaisa and Majulay, which were dried at 50 °C. The composition of the essential oil of the Bhaisa variety resembled the profile of samples dried for 48 and 72 h, as described in Table S2, with main components such as geraniol and geranyl acetate.

2.2. Multivariate analysis

The chemical composition was evaluated through multivariate analysis using the Principal Components technique (PCA). The two main components explain 88.38% of the results; the variance for PCA1 was 52.80%, and for PCA2, it was 35.58%. It is possible to observe the grouping tendency of the different drying methods so that two distinct clusters are formed, called clusters A and B, as illustrated in Figures S2 and S3. The fresh ginger essential oil sample was grouped in cluster A with the compounds α-curcumene, α-farnesene, α-zingiberene, and sesquiphellandrene. Cluster B grouped the essential oil samples with the 24h, 48h, and 72h treatments.

Within Cluster B, we observed two distinct subgroups, one comprising the 24h samples and the other comprising the 48h and 72h samples (Figure S4). To elucidate these groupings further, we constructed a dendrogram using the average group linkage method (UPGMA). Figure S4 shows that this dendrogram identifies Cluster B(1), representing the ginger chemotype dried for 24 h. Similarly, Cluster B(2) combines the chemotypes dried for 48 h and 72 h, indicating their similarities and grouping.

Our analysis of the compounds forming Cluster B and its subdivisions, B(1) and B(2), was guided by the vectors shown in the biplot of Figure S2. Cluster B(1), which represents the 24h samples, showed a strong correlation with α-pinene, camphene, β-myrcene, β-phelladrene, eucalyptol, linalool, borneol, α-terpineol, neral, geranial, and nerolidyl acetate. The samples from Cluster B(2), which are ginger dried for 48h and 72h, exhibited similarities, with the compounds responsible and correlated to this chemotype being citronellol, geraniol, citronellyl acetate, geranyl acetate, elemol, germacrene B, caryophyllene oxide, viridiflorol, β-eudesmol, elemol acetate, nerolidol and farnesyl acetate. Importantly, our results demonstrate that adjusting the drying time makes it possible to obtain an oil chemotype that aligns with the desired groups between sesquiterpenes and monoterpenes, both hydrogenated and oxygenated.

3. Conclusion

Research results with different drying times showed increased essential oil yield with drying time. Analysis of the chemical composition revealed that α-zingiberene is the predominant component in the fresh sample; however, after 24 h of drying, there was a reduction in this compound, with geranial becoming the main component. In samples dried for 48 and 72 h, several monoterpenes presented similar relative areas, including geraniol acetate, geranial, and geraniol. Multivariate analysis using PCA clearly showed three chemotypes, one grouping the fresh samples into one group, in the other the 24, 48, and 72 h samples, with a subgroup occurring within this group with the 48h and 72h samples grouping.

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References

Aabha R, Tewari G, Pande C, Negi N, Bisht M, Kanyal B, Singh S, Prakash O. 2024. Effect of drying methods on the essential oil components and antioxidant potential of rhizomes of the spice *Zinger officinale* Roscoe. (Zingiberaceae). The Bioscan. 18(2):149–158.

Abdullahi A, Khairulmazmi A, Yasmeen S, Ismail IS, Norhayu A, Sulaiman MR, Ahmed OH, Ismail MR. 2020. Phytochemical profiling and antimicrobial activity of ginger (*Zingiber officinale*) essential oils against important phytopathogens. Arab J Chem. 13(11):8012–8025. doi:10.1016/j.arabjc.2020.09.031.

An K, Zhao D, Wang Z, Wu J, Xu Y, Xiao G. 2016. Comparison of different drying methods on Chinese ginger (*Zingiber officinale* Roscoe): Changes in volatiles, chemical profile, antioxidant properties, and microstructure. Food Chem. 197 Pt B:1292–1300. doi:10.1016/j.foodchem.2015.11.033.

Bag BB. 2018. Ginger Processing in India (*Zingiber officinale*): A Review. IJCMAS. 7(04):1639–1651. doi:10.20546/ijcmas.2018.704.185.

Baruah J, Pandey SK, Begum T, Sarma N, Paw M, Lal M. 2019. Molecular diversity assessed amongst high dry rhizome recovery Ginger germplasm (*Zingiber officinale* Roscoe) from NE-India using RAPD and ISSR markers. Ind Crops Prod. 129:463–471. doi:10.1016/j.indcrop.2018.12.037.

Das A, Dey S, Sahoo RK, Sahoo S, Subudhi E. 2019. antibiofilm and antibacterial activity of essential oil bearing *Zingiber officinale* Rosc. (ginger) rhizome against multi-drug resistant isolates. J. Essent. Oil-Bear. Plants. 22(4):1163–1171. doi:10.1080/0972060X.2019.1683080.

Dorneles LDNS, Goneli ALD, Cardoso CAL, da Silva CB, Hauth MR, Oba GC, Schoeninger V. 2019. Effect of air temperature and velocity on drying kinetics and essential oil composition of *Piper umbellatum* L. leaves. Ind Crops Prod. 142:111846. doi:10.1016/j.indcrop.2019.111846.

Feng J, Du Z, Zhang L, Luo W, Zheng Y, Chen D, Pan W, Yang Z, Lin L, Xi L. 2018. chemical composition and skin protective effects of essential oil obtained from ginger (*Zingiber officinale* Roscoe). J Essent Oil-Bear Plants. 21(6):1542–1549. doi:10.1080/0972060X.2018.1533436.

Foko GAD, Tchakouan AM, Abe H, Zeukeng F, Awono-Ambene HP, Njiokou F, Tamesse JL. 2018. Chemical composition and toxicity of *Zingiber officinale* (Roscoe, 1807) (Zingiberaceae) essential oil on the aquatic stages of the malaria vector Anopheles coluzzii. Int Res J Public Environ Health. 5(2):25–31. doi:10.15739/irjpeh.18.005.

Ghafoor K, Al Juhaimi F, Özcan MM, Uslu N, Babiker EE, Mohamed Ahmed IA. 2020. Total phenolics, total carotenoids, individual phenolics and antioxidant activity of ginger (*Zingiber officinale*) rhizome as affected by drying methods. LWT. 126:109354. doi:10.1016/j.lwt.2020.109354.

Gunasena MT, Rafi A, Mohd Zobir SA, Hussein MZ, Ali A, Kutawa AB, Abdul Wahab MA, Sulaiman MR, Adzmi F, Ahmad K. 2022. Phytochemicals profiling, antimicrobial activity and mechanism of action of essential oil extracted from ginger (*Zingiber officinale* Roscoe cv. Bentong) against *Burkholderia glumae* causative agent of bacterial panicle blight disease of rice. Plants (Basel). 11(11):1466. doi:10.3390/plants11111466.

Huang B, Wang G, Chu Z, Qin L. 2012. effect of oven drying, microwave drying, and silica gel drying methods on the volatile components of ginger *(Zingiber officinale* Roscoe) by HS-SPME-GC-MS. Dry Technol. 30(3):248–255. doi:10.1080/07373937.2011.634976.

Jayashree E, Visvanathan R, Zachariah J. 2014. Quality of dry ginger (*Zingiber officinale*) by different drying methods. J Food Sci Technol. 51(11):3190–3198. doi:10.1007/s13197-012-0823-8.

Jayasundara NDB, Arampath P. 2021. Effect of variety, location & maturity stage at harvesting, on essential oil chemical composition, and weight yield of *Zingiber officinale* roscoe grown in Sri Lanka. Heliyon. 7(3):e06560. doi:10.1016/j.heliyon.2021.e06560.

Kalhoro MT, Zhang H, Kalhoro GM, Wang F, Chen T, Faqir Y, Nabi F. 2022. Fungicidal properties of ginger (*Zingiber officinale*) essential oils against *Phytophthora colocasiae*. Sci Rep. 12(1):2191. doi:10.1038/s41598-022-06321-5.

Kamal GM, Nazi N, Sabir A, Saqib M, Zhang X, Jiang B, Khan J, Noreen A, Uddin J, Murtaza S. 2023. Yield and chemical composition of ginger essential oils as affected by inter-varietal variation and drying treatments of rhizome. Separations. 10(3):186. doi:10.3390/separations10030186.

Liu Y, Liu J, Zhang Y. 2019. Research progress on chemical constituents of *Zingiber officinale Roscoe*. Biomed Res Int. 2019:5370823–5370821. doi:10.1155/2019/5370823.

Mahboubi M. 2019. *Zingiber officinale* Rosc. essential oil, a review on its composition and bioactivity. Clin Phytosci. 5(1):6. doi:10.1186/s40816-018-0097-4.

Munda S, Dutta S, Haldar S, Lal M. 2018. Chemical analysis and therapeutic uses of ginger (*Zingiber officinale* Rosc.) essential oil: a review. J Essent Oil-Bear Plants. 21(4):994–1002. doi:10.1080/0972060X.2018.1524794.

Noshirvani N, Ghanbarzadeh B, Gardrat C, Rezaei MR, Hashemi M, Le Coz C, Coma V. 2017. Cinnamon and ginger essential oils to improve antifungal, physical and mechanical properties of chitosan-carboxymethyl cellulose films. Food Hydrocoll. 70:36–45. doi:10.1016/j.foodhyd.2017.03.015.

Osae R, Apaliya MT, Kwaw E, Chisepo MTR, Yarley OPN, Antiri EA, Alolga RN. 2021. Drying techniques affect the quality and essential oil composition of Ghanaian ginger (*Zingiber officinale* Roscoe). Ind Crops Prod. 172:114048. doi:10.1016/j.indcrop.2021.114048.

Peixoto PMC, Júlio AA, Jesus EG, Venancio AN, Parreira LA, Santos MFC, Menini L. 2024. Fungicide potential of citronella and tea tree essential oils against tomato cultivation's phytopathogenic fungus *Fusarium oxysporum* f. sp. *lycopersici* and analysis of their chemical composition by GC/MS. Nat Prod Res. 38(4):667–672. doi:10.1080/14786419.2023.2184358.

Romoli JCZ, Silva MV, Pante GC, Hoeltgebaum D, Castro JC, Oliveira da Rocha GH, Capoci IRG, Nerilo SB, Mossini SAG, Micotti da Gloria E, et al. 2022. Anti-mycotoxigenic and antifungal activity of ginger, turmeric, thyme and rosemary essential oils in deoxynivalenol (DON) and zearalenone (ZEA) producing *Fusarium graminearum*. Food Addit Contam Part A Chem Anal Control Expo Risk Assess. 39(2):362–372. doi:10.1080/19440049.2021.1996636.

Sasidharan I, Menon AN. 2010. Comparative chemical composition and antimicrobial activity fresh & dry ginger oils (*Zingiber officinale* Roscoe). Int J Curr Pharm Res. 2(4):40–43. http://naturalingredient.org/wp/wp-content/uploads/235.pdf.

Sasidharan I, Venugopal VV, Menon AN. 2012. Essential oil composition of two unique ginger (*Zingiber officinale* Roscoe) cultivars from Sikkim. Nat Prod Res. 26(19):1759–1764. doi:10.1080/14786419.2011.571215.

Shahrajabian MH, Sun W, Cheng Q. 2019. Clinical aspects and health benefits of ginger (*Zingiber officinale*) in both traditional Chinese medicine and modern industry. Acta Agr Scand B-S P. 69(6):546–556. doi:10.1080/09064710.2019.1606930.

Sharma P, Singh V, Ali M. 2016. Chemical composition and antimicrobial activity of fresh rhizome essential oil of *Zingiber Officinale* Roscoe. Phcogj. 8(3):185–190. doi:10.5530/pj.2016.3.3.

Snuossi M, Trabelsi N, Ben Taleb S, Dehmeni A, Flamini G, De Feo V. 2016. *Laurus nobilis*, *Zingiber officinale* and *Anethum graveolens* essential oils: composition, antioxidant and antibacterial activities against bacteria isolated from fish and shellfish. Molecules. 21(10):1414. doi:10.3390/molecules21101414.

Vaz MSM, Simionatto E, De Almeida de Souza GH, Fraga TL, De Oliveira GG, Coutinho EJ, Oliveira dos Santos MV, Simionatto S. 2022. *Zingiber officinale* Roscoe essential oil: an alternative strategy in the development of novel antimicrobial agents against MDR bacteria. Ind Crops Prod. 185:115065. doi:10.1016/j.indcrop.2022.115065.

Wang J, Li Y, Lu Q, Hu Q, Liu P, Yang Y, Li G, Xie H, Tang H. 2021. Drying temperature affects essential oil yield and composition of black cardamom (*Amomum tsao-ko*). Ind Crops Prod. 168:113580. doi:10.1016/j.indcrop.2021.113580.

Wang X, Shen Y, Thakur K, Han J, Zhang JG, Hu F, Wei ZJ. 2020. Antibacterial activity and mechanism of ginger essential oil against *Escherichia coli* and *Staphylococcus aureus*. Molecules. 25(17):3955. doi:10.3390/molecules25173955.

Yu DX, Guo S, Wang JM, Yan H, Zhang ZY, Yang J, Duan JA. 2022. Comparison of different drying methods on the volatile components of ginger (*Zingiber officinale* Roscoe) by HS-GC-MS coupled with fast GC e-nose. Foods. 11(11):1611. doi:10.3390/foods11111611.

Zagórska J, Czernicka-Boś L, Kukula-Koch W, Iłowiecka K, Koch W. 2023. Impact of thermal processing on the selected biological activities of ginger rhizome—A review. Molecules. 28(1):412. doi:10.3390/foods11111611.

Zhang S, Kou X, Zhao H, Mak KK, Balijepalli MK, Pichika MR. 2022. *Zingiber officinale* var. rubrum: red ginger's medicinal uses. Molecules. 27(3):775. doi:10.3390/molecules27030775.