A REVIEW ON ANALYTICAL APPROACHES FOR IDENTIFYING CITRUS PHYTOCHEMICALS

UMME SHARMIN, AKM MOYEENUL HUQ, JAMIA AZDINA JAMAL

References:

1. E. González-Molina, R. Domínguez-Perles, D. A. Moreno, and C. García-Viguera, “Natural bioactive compounds of Citrus limon for food and health,” *J. Pharm. Biomed. Anal.*, vol. 51, no. 2, pp. 327–345, 2010, doi: 10.1016/j.jpba.2009.07.027.
2. Y. H. Xin, Y. X. Wu, B. Qiao, L. Su, S. Q. Xie, and P. Ling, “Evaluation on the phenotypic diversity of Calamansi (Citrus microcarpa) germplasm in Hainan island,” *Sci. Rep.*, vol. 12, no. 1, pp. 1–12, 2022, doi: 10.1038/s41598-021-03775-x.
3. A. Duarte, J. Fernandes, J. Bernardes, and G. Miguel, “Citrus as a component of the mediterranean diet,” *J. Spat. Organ. Dyn.*, vol. IV, no. 4, pp. 289–304, 2016, [Online]. Available: https://www.jsod-cieo.net/journal/index.php/jsod/article/view/78
4. Z. Aumeeruddy-Elalfi, A. Gurib-Fakim, and M. F. Mahomoodally, “Chemical composition, antimicrobial and antibiotic potentiating activity of essential oils from 10 tropical medicinal plants from Mauritius,” *J. Herb. Med.*, vol. 6, no. 2, pp. 88–95, 2016, doi: 10.1016/j.hermed.2016.02.002.
5. M. H. R. O. Abdullah, P. E. Ch’ng, and N. A. Yunus, “Some Physical Properties of Musk Lime (Citrus,” *World Acad. Sci. Eng. Technol.*, vol. 72, no. 12, pp. 1079–1082, 2012.
6. S. M. Jeong *et al.*, “Effect of heat treatment on the antioxidant activity of extracts from citrus peels,” *J. Agric. Food Chem.*, vol. 52, no. 11, pp. 3389–3393, 2004, doi: 10.1021/jf049899k.
7. R. K. Saini *et al.*, “Bioactive Compounds of Citrus Fruits: A Review of Composition and Health Benefits of Carotenoids, Flavonoids, Limonoids, and Terpenes,” *Antioxidants*, vol. 11, no. 2, 2022, doi: 10.3390/antiox11020239.
8. H. Z. and A. R. Z. R. Suri, A. Crozier, “On-line high-performance liquid chromatography analysis of the antioxidant activity of phenolic compounds in selected tropical citrus,” *Mol. Nutr. Food Res.*, vol. 49, no. 1, pp. 52–60, 2016, doi: 10.1002/mnfr.200400064.
9. F. Agouillal, Z. M. Taher, H. Moghrani, N. Nasrallah, and H. El Enshasy, “A Review of Genetic Taxonomy, Biomolecules Chemistry and Bioactivities of Citrus hystrix DC,” *Biosci. Biotechnol. Res. Asia*, vol. 14, no. 1, pp. 285–305, 2017, doi: 10.13005/bbra/2446.
10. Lim TK Lim, «Edible Medicinal and Non Medicinal Plants», vol. 4. Springer Dordrecht Heidelberg London New York. 2012.
11. S. Doherty, “History of evidence-based medicine. Oranges, chloride of lime and leeches: Barriers to teaching old dogs new tricks,” *EMA - Emerg. Med. Australas.*, vol. 17, no. 4, pp. 314–321, 2005, doi: 10.1111/j.1742-6723.2005.00752.x.
12. A. Abirami, G. Nagarani, and P. Siddhuraju, “The medicinal and nutritional role of underutilized citrus fruit-Citrus hystrix (Kaffir lime): A review,” *Drug Invent. Today*, vol. 6, no. 1, pp. 1–5, 2014.
13. T. Mencherini *et al.*, “HPLC-PDA-MS and NMR characterization of a hydroalcoholic extract of citrus aurantium L. Var. amara Peel with antiedematogenic activity,” *J. Agric. Food Chem.*, vol. 61, no. 8, pp. 1686–1693, 2013, doi: 10.1021/jf302815t.
14. N. Narang and W. Jiraungkoorskul, “Anticancer activity of key lime, Citrus aurantifolia,” *Pharmacogn. Rev.*, vol. 10, no. 20, pp. 118–122, 2016, doi: 10.4103/0973-7847.194043.
15. J. R. Patil, K. N. Chidambara Murthy, G. K. Jayaprakasha, M. B. Chetti, and B. S. Patil, “Bioactive compounds from mexican lime (Citrus aurantifolia) juice induce apoptosis in human pancreatic cells,” *J. Agric. Food Chem.*, vol. 57, no. 22, pp. 10933–10942, 2009, doi: 10.1021/jf901718u.
16. J. R. Patil, G. K. Jayaprakasha, K. N. Chidambara Murthy, S. E. Tichy, M. B. Chetti, and B. S. Patil, “Apoptosis-mediated proliferation inhibition of human colon cancer cells by volatile principles of Citrus aurantifolia,” *Food Chem.*, vol. 114, no. 4, pp. 1351–1358, 2009, doi: 10.1016/j.foodchem.2008.11.033.
17. M. Addi, A. Elbouzidi, M. Abid, D. Tungmunnithum, A. Elamrani, and C. Hano, “An Overview of Bioactive Flavonoids from Citrus Fruits,” *Appl. Sci.*, vol. 12, no. 1, pp. 1–15, 2022, doi: 10.3390/app12010029.
18. O. S. Enejoh, I. O. Ogunyemi, M. S. Bala, I. S. Oruene, M. M. Suleiman, and S. F. Ambali, “Ethnomedical Importance of Citrus Aurantifolia (Christm) Swingle,” *Pharma Innov. J.*, vol. 4, no. 8, pp. 1–6, 2015, [Online]. Available: www.thepharmajournal.com
19. R. Costa, M. Russo, S. De Grazia, E. Grasso, P. Dugo, and L. Mondello, “Thorough investigation of the oxygen heterocyclic fraction of lime (Citrus aurantifolia (Christm.) Swingle) juice,” *J. Sep. Sci.*, vol. 37, no. 7, pp. 792–797, 2014, doi: 10.1002/jssc.201300986.
20. R. S. Lemes *et al.*, “Chemical composition and antibacterial activity of essential oils from Citrus

aurantifolia leaves and fruit peel against oral pathogenic bacteria," *An. Acad. Bras. Cienc.*, vol. 90, no. 2, pp. 1285–1292, 2018, doi: 10.1590/0001-3765201820170847.
21. F. M. Almenario and S. D. Jacinto, "Hplc isolate from the leaves of kaffir lime (Citrus hystrix dc) exhibits selective cytotoxicity against human breast adenocarcinoma cell line, mcf-7," *Philipp. J. Sci.*, vol. 150, no. 1, pp. 111–121, 2021, doi: 10.56899/150.01.09.
22. S. M. Poulose, E. D. Harris, and B. S. Patil, "Antiproliferative effects of citrus limonoids against human neuroblastoma and colonic adenocarcinoma cells," *Nutr. Cancer*, vol. 56, no. 1, pp. 103–112, 2006, doi: 10.1207/s15327914nc5601_14.
23. E. Husni, F. Yeni, and Dachriyanus, "Chemical Contents Profile of Essential Oil from Calamansi (Citrus microcarpa Bunge) Peels and Leaves and Its Antibacterial Activities," *Atl. Press*, vol. 40, no. Iccscp, p. 320, 2021, [Online]. Available: https://www.atlantis-press.com/proceedings/iccscp-21/125962517
24. M. W. Cheong *et al.*, "Characterisation of calamansi (Citrus microcarpa). Part II: Volatiles, physicochemical properties and non-volatiles in the juice," *Food Chem.*, vol. 134, no. 2, pp. 696–703, 2012, doi: 10.1016/j.foodchem.2012.02.139.
25. T. N. T. Nguyen, T. N. N. Huynh, V. T. Tran, C. H. Dang, T. K. D. Hoang, and T. D. Nguyen, "Physicochemical characterization and bioactivity evaluation of essential oils from Citrus microcarpa Bunge leaf and flower," *J. Essent. Oil Res.*, vol. 30, no. 4, pp. 285–292, 2018, doi: 10.1080/10412905.2018.1435428.
26. "The Role of GABA," vol. 494, no. March, pp. 477–494, 2006, doi: 10.1002/ddr.
27. S. Jain, P. Arora, and H. Popli, "A comprehensive review on Citrus aurantifolia essential oil: its phytochemistry and pharmacological aspects," *Brazilian J. Nat. Sci.*, vol. 3, no. 2, p. 354, 2020, doi: 10.31415/bjns.v3i2.101.
28. G. Xu, X. Ye, D. Liu, Y. Ma, and J. Chen, "Composition and distribution of phenolic acids in Ponkan (Citrus poonensis Hort. ex Tanaka) and Huyou (Citrus paradisi Macf. Changshanhuyou) during maturity," *J. Food Compos. Anal.*, vol. 21, no. 5, pp. 382–389, 2008, doi: 10.1016/j.jfca.2008.03.003.
29. M. E. Lucchesi, F. Chemat, and J. Smadja, "Solvent-free microwave extraction of essential oil from aromatic herbs: Comparison with conventional hydro-distillation," *J. Chromatogr. A*, vol. 1043, no. 2, pp. 323–327, 2004, doi: 10.1016/j.chroma.2004.05.083.
30. A. Kabir, F. Cacciagrano, A. Tartaglia, M. Lipsi, H. I. Ulusoy, and M. Locatelli, "Analysis of monoterpenes and monoterpenoids," *Recent Adv. Nat. Prod. Anal.*, pp. 274–286, 2020, doi: 10.1016/B978-0-12-816455-6.00007-X.
31. M. Vinatoru, "An overview of the ultrasonically assisted extraction of bioactive principles from herbs," *Ultrason. Sonochem.*, vol. 8, no. 3, pp. 303–313, 2001, doi: 10.1016/S1350-4177(01)00071-2.
32. G. F. Barbero, A. Liazid, M. Palma, and C. G. Barroso, "Ultrasound-assisted extraction of capsaicinoids from peppers," *Talanta*, vol. 75, no. 5, pp. 1332–1337, 2008, doi: 10.1016/j.talanta.2008.01.046.
33. N. Bousbia, M. A. Vian, M. A. Ferhat, B. Y. Meklati, and F. Chemat, "A new process for extraction of essential oil from Citrus peels: Microwave hydrodiffusion and gravity," *J. Food Eng.*, vol. 90, no. 3, pp. 409–413, 2009, doi: 10.1016/j.jfoodeng.2008.06.034.
34. S. Ikawati, M. Dhuha, and T. Himawan, "Bioactivity of Citrus hystrix D.C. Leaf Extract Against Cigarette Beetle Lasioderma serricorne (F.)," *J. Trop. Life Sci.*, vol. 7, no. 3, pp. 189–196, 2017, doi: 10.11594/jtls.07.03.01.
35. L. Galovičová *et al.*, "The Potential Use of Citrus aurantifolia L. Essential Oils for Decay Control, Quality Preservation of Agricultural Products, and Anti-Insect Activity," *Agronomy*, vol. 12, no. 3, pp. 1–12, 2022, doi: 10.3390/agronomy12030735.
36. S. Roowi, R. Muse, M. Mahmood, and M. Sukari, "Effect of elicitors on the production of naringin and rutin in leech lime (Citrus hystrix) callus," *J. Trop. Agric. Food Sci.*, vol. 30, no. 1, pp. 89–94, 2002.
37. Y. A. Wijaya, D. Widyadinata, W. Irawaty, and A. Ayucitra, "Fractionation of phenolic compounds from kaffir lime (Citrus hystrix) peel extract and evaluation of antioxidant activity" *Reaktor*, vol. 17, no. 3, p. 111, 2017, doi: 10.14710/reaktor.17.3.111-117.
38. M. R. Loizzo *et al.*, "Evaluation of Citrus aurantifolia peel and leaves extracts for their chemical composition, antioxidant and anti-cholinesterase activities," *J. Sci. Food Agric.*, vol. 92, no. 15, pp. 2960–2967, 2012, doi: 10.1002/jsfa.5708.
39. D. Ningombam, H. Deliza, B. Debkumari, and M. D. Devi, "Phytochemical, Antimicrobial and Acute Toxicity Studies on Methanolic Extracts of Citrus medica L. and Citrus hystrix D. C. Fruits," *J. Pharm. Res. Int.*, vol. 33, pp. 52–67, 2021, doi: 10.9734/jpri/2021/v33i47b33096.
40. E. I. Elmongy *et al.*, "Antidiarrheal and Antibacterial Activities of Monterey Cypress Phytochemicals: In Vivo and In Vitro Approach," *Molecules*, vol. 27, no. 2, 2022, doi: 10.3390/molecules27020346.
41. M. P. T. Maw, P. Phattanawasin, C. Sukonpan, and N. Piyapolrungroj, "Possible Intestinal Absorption Enhancers from Citrus hystrix," *E3S Web Conf.*, vol. 141, pp. 1–5, 2020, doi: 10.1051/e3sconf/202014102003.
42. M. Barzalona and J. Casanova, "Chemical variability of the leaf oil of 113 hybrids from," no. April, pp. 152–163, 2008, doi: 10.1002/ffj.
43. S. P. Yo and C. H. Lin, "Qualitative and quantitative composition of the flavour components of Taiwan

calamondin and Philippine calamansi fruit," *Eur. J. Hortic. Sci.*, vol. 69, no. 3, pp. 117–124, 2004.
44. M. S. Al-Aamri, N. M. Al-Abousi, S. S. Al-Jabri, T. Alam, and S. A. Khan, "Chemical composition and in-vitro antioxidant and antimicrobial activity of the essential oil of Citrus aurantifolia L. leaves grown in Eastern Oman," *J. Taibah Univ. Med. Sci.*, vol. 13, no. 2, pp. 108–112, 2018, doi: 10.1016/j.jtumed.2017.12.002.
45. F. I. Abdullah and L. S. Chua, "High Throughput Comparison of 13 Herbal Plants Extracted by Heat-Refluxed and Heat-Pressurized Extraction Techniques Using Chemometrics," pp. 1–14, 2020.
46. S. Roowi and A. Crozier, "Flavonoids in tropical Citrus species," *J. Agric. Food Chem.*, vol. 59, no. 22, pp. 12217–12225, 2011, doi: 10.1021/jf203022f.
47. M. Russo, I. Bonaccorsi, R. Costa, A. Trozzi, P. Dugo, and L. Mondello, "Reduced time HPLC analyses for fast quality control of citrus essential oils," *J. Essent. Oil Res.*, vol. 27, no. 4, pp. 307–315, 2015, doi: 10.1080/10412905.2015.1027419.
48. D. Ningombam, H. Deliza, B. Debkumari, and M. D. Devi, "Phytochemical, Antimicrobial and Acute Toxicity Studies on Methanolic Extracts of Citrus medica L. and Citrus hystrix D. C. Fruits," *J. Pharm. Res. Int.*, no. October, pp. 52–67, 2021, doi: 10.9734/jpri/2021/v33i47b33096.
49. M. S. H. Akash and K. Rehman, *Essentials of pharmaceutical analysis*. 2019. doi: 10.1007/978-981-15-1547-7.
50. J. E. Adaway and B. G. Keevil, "Therapeutic drug monitoring and LC-MS/MS," *J. Chromatogr. B Anal. Technol. Biomed. Life Sci.*, vol. 883–884, pp. 33–49, 2012, doi: 10.1016/j.jchromb.2011.09.041.
51. R. Aparicio-Ruiz, D. L. García-González, M. T. Morales, A. Lobo-Prieto, and I. Romero, "Comparison of two analytical methods validated for the determination of volatile compounds in virgin olive oil: GC-FID vs GC-MS," *Talanta*, vol. 187, pp. 133–141, 2018, doi: 10.1016/j.talanta.2018.05.008.
52. T. Nowak *et al.*, "GC-FID method for high-throughput analysis of residual solvents in pharmaceutical drugs and intermediates," *Green Chem.*, vol. 18, no. 13, pp. 3732–3739, 2016, doi: 10.1039/c6gc01210h.
53. C. Dogaroiu and R. Sugden, "Practical implications of GC and HPLC methods for the analysis of drugs of abuse in blood," *Rom. J. Leg. Med.*, vol. 16, no. 2, pp. 95–102, 2008.
54. C. Hao, X. Zhao, and P. Yang, "GC-MS and HPLC-MS analysis of bioactive pharmaceuticals and personal-care products in environmental matrices," *TrAC - Trends Anal. Chem.*, vol. 26, no. 6, pp. 569–580, 2007, doi: 10.1016/j.trac.2007.02.011.
55. J. S. Félix, P. Alfaro, and C. Nerín, "Pros and cons of analytical methods to quantify surrogate contaminants from the challenge test in recycled polyethylene terephthalate," *Anal. Chim. Acta*, vol. 687, no. 1, pp. 67–74, 2011, doi: 10.1016/j.aca.2010.12.013.
56. M. A. LeBeau, M. A. Montgomery, M. L. Miller, and S. G. Burmeister, "Analysis of biofluids for gamma-hydroxybutyrate (GHB) and gamma-butyrolactone (GBL) by headspace GC-FID and GC-MS," *J. Anal. Toxicol.*, vol. 24, no. 6, pp. 421–428, 2000, doi: 10.1093/jat/24.6.421.
57. K. Jumtee, T. Bamba, and E. Fukusaki, "Fast GC-FID based metabolic fingerprinting of Japanese green tea leaf for its quality ranking prediction," *J. Sep. Sci.*, vol. 32, no. 13, pp. 2296–2304, 2009, doi: 10.1002/jssc.200900096.