Discover Applied Sciences

Review

Innovations and modifications of current extraction methods and techniques of citrus essential oils: a review

Augustine S. Brah[1] · **Collins Obuah**[2] · **Christian K. Adokoh**[3]

Received: 20 May 2024 / Accepted: 16 July 2024

Abstract

The genus Citrus of the Rutaceae family remains one of the beneficial fruit crops that produce high quantities of essential oils that have pharmaceutical, biological, and food preservative applications. Despite the numerous benefits of citrus essential oils (CEOs), there is a major challenge in choosing the most efficient extraction method(s) for large-scale production of quality CEOs to meet industrial, research, and domestic demands. This review provides a general overview of the listed citrus species, the chemical composition of their essential oils, medicinal uses, and the major methods of extraction of citrus essential oils from 10 selected citrus species. A meticulous, in-depth review of the various methods of CEOs extraction has been provided, along with their advantages, limitations, and novel modifications. This comprehensive literature review expounded on the current extraction methods for citrus essential oils and the various modifications developed to reduce the extraction time, excessive energy consumption, CO_2 production, and quality, as well as to improve the extraction yield.

Article Highlights

- General overview of ten (10) selected citrus species and their essential oil composition and applications.
- The advantages and disadvantages of various methods of extraction of citrus essential oils for research and industrial applications.
- Innovative modifications of the conventional and advanced methods for extraction of citrus essential oils have better efficiency.

Abbreviations

5-MOP-5	Methoxy psoralen
ATR-FTIR	Attenuated total reflection fourier-transform infrared spectroscopy
CEOs	Citrus essential oils
DRIFT	Diffuse reflectance infrared Fourier transform
EOs	Essential oils
FESEM	Field emission scanning electron microscopy
HD	Hydro distillation
HPLC	High-performance thin-layer chromatography

✉ Christian K. Adokoh, cadokoh@ucc.edu.gh | [1]Department of Biomedical Sciences, School of Allied Health Sciences, University of Cape Coast, Cape Coast, Ghana. [2]Department of Chemistry, University of Ghana, Legon, Ghana. [3]Department of Forensic Sciences, School of Biological Sciences, University of Cape Coast, Cape Coast, Ghana.

HPLC-ToF–MS	High-performance thin-layer chromatography time of flight mass spectrometry
HPTLC	High-performance thin-layer chromatography
HSCC	High-speed counter-current chromatography
GC–MS	Gas chromatography-mass spectrometry
GC–C-IRMS	Chromatography–combustion-isotope ratio mass spectrometry
GC-FID	Gas chromatography with flame-ionization detection
GC-O	Gas chromatography olfactometry
LDL	Low-density lipoprotein
MAE-IL	Ionic liquid-based microwave-assisted extraction
MASD	Microwave assisted steam distillation
MASE	Microwave-assisted solvent extraction
MDGC-MS	Multi-dimensional gas chromatography-mass spectrometry
MHG	Microwave hydro-diffusion and gravity
NMR	Nuclear magnetic resonance
RP-HPLC	Reversed phase high-performance thin-layer chromatography
SC-CO_2	Supercritical carbon dioxide
SFE	Supercritical fluid extraction
SFME	Solvent-free microwave extraction
SD	Steam distillation
UAE	Ultrasound-assisted extraction
UHPLC-TOF–MS	Ultra-high performance liquid chromatography time-of-flight mass
UA-HS-SPME	Ultrasonic-assisted headspace solid phase micro-extraction

1 Introduction

The *Citrus* genus is one of the most popular members of the family Rutaceae. The *Citrus* genus is made up of 17 plant species, which are mostly trees or shrubs and are widely cultivated in tropical and subtropical regions of the world. Even though *Citrus* species are cultivated in different parts of the world, their origin can be traced to Southern China, Korea, Japan, Northern Myanmar, and India [1, 2]. Citrus is one of the most cultivated fruit plants in the world, and its production was around 144 million metric tons in 2020 [3]. Between 50 and 60% of citrus fruits are consumed freshly, while the remainder is processed into different products by industries [4]. China, Brazil, the USA, India, and Mexico are the largest producers of citrus fruits. The common Citrus species grown for their fruits include sweet orange (*Citrus sinensis* Osbeck), key lime (*Citrus aurantifolia (Christm.) Swingle*), bergamot orange (*Citrus bergamia* Risso), bitter orange (*Citrus aurantium* L.), lemon (*Citrus limon* L.), mandarin orange (*Citrus reticulata Blanco*), grapefruit (*Citrus × paradisi*), kumquat (*Citrus japonica*), and yuzu (*Citrus junos* Siebold ex Tanaka). Citrus plants are mainly valued for fruits that are rich in ascorbic acid, flavonoids, and polyphenols, which have vital health benefits [5]. There is growing interest in the use of natural products in disease treatment, and several studies have highlighted the medicinal benefits of citrus species and their derived bioactive compounds. Citrus fruits, seeds, juices, and fruit peel/rind oils have been used in the formulation and preparation of most products, such as pharmaceuticals, food preservatives, cosmetics, detergents, air fresheners, deodorants, and sweet-scented perfumes [6, 7]. The fruit peels, leaves, aerials, seeds, and flowers of citrus plants contain volatile essential oils characterized by a sweet-scented aroma and possessing vital phytochemicals [8, 9]. Essential oils primarily contain a mixture of aromatic compounds stored in special parts of the plants, specifically in the oil glands of the fruit peels, leaves, seeds, and flowers [4]. These essential oils are endowed with several medicinal benefits, which include antimicrobial, aromatherapy, anti-inflammatory, anti-diabetic, anti-cancer, and insecticidal properties [10, 11]. The biological activities of Citrus essential oils are attributed to the presence of a mixture of complex compounds, mainly terpenes, monoterpenes, alcohols, aldehydes, esters, and ketones [12]. Most of the compounds are volatile and thus sensitive to conditions like high temperatures (heat), pressure, oxygenation, and light [13]. Also, the composition and quantities of these compounds can vary significantly in various citrus essential oils depending on the species, climatic conditions, geographical location, and methods of extraction and storage of the essential oils [14]. The yield, composition, and quality of the citrus essential oil differ significantly depending on the pre-extraction treatment and the choice of extraction method(s) [15]. The main challenge is to determine the efficient extraction method and the conditions under which the constituents of the essential oil reflect the actual composition and quality of the plant storage parts

[16]. Efficient methods of extraction are needed to preserve the vital constituents, increase the yield, and limit the variations in the components [17]. In this review, a brief description of 10 selected citrus species will be given, and the various methods of extraction and purification of their essential oils will be discussed extensively by comparing their efficiencies, disadvantages, innovations, and modifications.

2 Methodology

In this review, we reviewed general scientific articles or publications, conference papers, book chapters, and theses indexed in different databases, including, Scopus, PubMed, Wiley, Taylor & Francis, Springer, Google Scholar, Science Direct, and Web of Science. The review focused on 10 species of the Citrus genus by elucidating their general overview of the plants, biological applications, methods of extraction, and detection or quantification of their essential oils. The review covered essential oils extracted from the following species, lemon (*C.limon L.*), sweet orange (*Citrus sinensis L.* Osbeck), mandarin orange (*Citrus reticulata Blanco*), lime (*Citrus aurantifolia (Christm.) Swingle*), Bergamot orange (*Citrus bergamia Risso*), bitter orange (*Citrus aurantium L.*), mandarin coleopatra citrus (*Citrus reshni*), grapefruit (*Citrus paradisi*), Kumquat (*Citrus japonica*), and yuzu (*Citrus junos*). The search terms used were "citrus species," "citrus essential oil extraction," "essential oil extraction methods," "steam distillation," "cold pressing," "solvent extraction," "hydro-distillation," "microwave-assisted extraction," "supercritical fluid extraction," and "ultrasound-assisted extraction."

3 General overview of ten selected *citrus* species

3.1 Sweet orange (*Citrus* sinensis L. Osbeck)

Sweet orange, *Citrus sinensis* (L) Osbeck, is one of the widely cultivated citrus species with increased production in different parts of the world, mostly for the consumption of fruits due to its nutritional and flavoring value [18]. Apart from their nutritional value, they are also a rich source of essential oils with several applications in pharmaceuticals, food processing and storage, perfumery, and cosmetics [11]. Sweet orange (*C. sinensis*) is commonly cultivated in subtropical regions and produced in large quantities in different parts of the world. It accounts for approximately 70% of all yearly production of citrus species [19]. The annual production of *C. sinensis* is reported to be the highest among most fruits with approximately 146.5 million tons in 2017 [19–21] and is mainly produced by countries like Brazil, the USA, Mexico, China, and Spain [22]. *C. sinensis* essential oil serves as the dominant source of monoterpene hydrocarbons and appreciable levels of myrcene, β-pinene, and sabinene [23]. Other volatile constituents are either a mixture of monoterpene (limonene) and sesquiterpene, hydrocarbons and their oxygenated derivatives [24]. Traditionally, the fruits of *C. sinensis* serve as a rich source of vitamin C, thus potent in boosting the immune system with its rich stores of antioxidants [25]. Besides, they have been used in treating various ailments and conditions, including, constipation, cough, common cold, depression, and others [26]. Essential oils of *C. sinensis* have exhibited antibacterial, antifungal, anti-inflammatory, radical scavenging, and anxiolytic [27] effects.

3.2 Bitter orange (*Citrus* aurantium L.)

Bitter orange (*Citrus aurantium L.*) differs from sweet orange by the bitterness of its rind and the relatively high acidity of its pulp [22]. Its peel has been used as a source of flavor for soft drinks, baked foods, and liquors, and aromatizes a lot of drugs [28]. Different studies have reported D-limonene as the major volatile constituent of bitter orange oil, which forms about 93% of its composition, and other components including monoterpene, sesquiterpenes, oxygenated compounds, and aromatic alcohols [22, 29]. The concentrations of aliphatic aldehydes, oxygen-containing, monoterpenes, and sesquiterpenes in the ripe, bitter orange peel essential oil are much higher than in the unripe peels [30]. This species has been used in the treatment of several conditions such as anxiety, gastrointestinal disorders, and obesity [29, 31]. *C. aurantium* essential oils have shown significant biological properties, including radical scavenging, anticancer, anxiolytic, and antibacterial effects [5, 32].

3.3 Key lime (*Citrus* aurantifolia (Christm.) swingle)

Citrus aurantifolia is a flowering plant from the family Rutaceae, an important species in the genus *Citrus* commonly known as lime. It is a native of Southern Asia and commonly cultivated in the West Indies, the US, and South America [33]. The essential oil contains both terpenes and non-terpenoid derivatives and consists mainly of alcohol, esters, acids, aldehydes, amines, and oxides [34]. Chemical profiling investigations via steam distillation have shown that the peel oil contains nine (9) phytochemicals; Germacrene isomers (61.2%), Pinene (14%), Linalool dimer (2.9%), Bornane (11%), Citral (2.9%), Anethole (1.5%), Anisole (1.1%), Safole (0.3%), and Demitol (0.6%) [35]. These constituents and others are believed to contribute immensely to the medicinal properties of *C. aurantifolia* oil [36]. *C. aurantifolia* essential oils have promising biological properties such as antibacterial, anthelminthic, anti-inflammatory, anti-diabetic, and radical scavenging effects [5, 37].

3.4 Lemon (*Citrus* limon L. Osbeck)

It is a small evergreen medicinal plant that belongs to the genus *Citrus* and the family Rutaceae [38]. Lemon is commonly grown in cooler summer regions, with the USA and Italy being the largest producers. The main constituents of lemon essential oil are terpenes (78.8%); limonene (48%) and β-terpinene (17%) according to Sun, Chen, Zhang, Liu, Ma and Zhang [39]. The essential oil of *C. limon* consists of a mixture of alcohols, acids, aldehydes, and esters, and among the hydrocarbon monoterpenes, those that occur in appreciable quantities are D-limonene, β-pinene, γ-terpinene, and *p*-cymene [22]. GC/MS analyses of *C. limon* essential oil identified three phytochemical groups (monoterpene hydrocarbons (88.69%), oxygenated monoterpenes, and sesquiterpene hydrocarbons) [40]. In all, 37 volatile constituents were observed, with D-limonene (59.48%) and β-pinene (12.75%) as the major constituents. Traditionally, their essential oils have numerous health benefits and have been used as astringents, diuretics, antimigraines, and also for relief from fever, colds, and flu [41]. The lemon essential oil has been touted as a home health remedy as people claim can reduce anxiety and depression, ease morning sickness, promote healthier skin, act as a pain reliever, help breathe easier, soothe a sore throat, and help one feel alert and concentrated [42]. Most of these claims have been substantiated and confirmed in the literature. Various studies have reported the medicinal effects of *C. limon* essential oil which include antibacterial, antifungal, radical scavenging, and insecticidal [43, 44] activities.

3.5 Bergamot (*Citrus* bergamia Risso)

The *Citrus bergamia* Risso plant belongs to the genus Citrus of the family Rutaceae and known and used for centuries in south Italia (Calabria). It is reported to be a hybrid between lemon (limon, Burm.f.) and *Citrus aurantium* L. (Sour orange) or arises from a mutation of Lemon [45], and is well known for its unique fruits (bergamot). The essential oil from its peels is commonly used for perfume [6]. The greenish or reddish-brown colored essential volatile oil of bergamot is obtained by rasping and cold pressing and has a characteristic bitter taste and pleasant odor [46]. Bergamot essential is peculiar because of its phototoxic effect which is normally attributed to the presence of bergapten or 5-methoxy psoralen (5-MOP), a naturally occurring compound of the furanocoumarin (psoralens) family. Some of the major compounds in *C. bergamia* Risso essential oil include limonene, linalyl acetate, linalool, γ-terpinene, and β-pinene [47]. The oil also contains mainly monoterpene and sesquiterpene hydrocarbons, in addition to aliphatic aldehydes, alcohol, and esters [48]. Several studies have revealed the enormous biological potential of *C. bergamia* essential oil some of which include: anti-cholesterol, anxiolytic anticancer, anti-inflammatory, antifungal, and antibacterial effects [5, 49].

3.6 Grapefruit (*Citrus x paradisi* Macfady)

Citrus paradisi, also called grapefruit, is a citrus plant with bitter fruits commonly grown in the tropics and subtropics [50]. Reports showed that it was discovered in Barbados on the Island of the Caribbean in the early nineteenth century and was later brought to Texas in 1821 [51]. It has become a worldwide commercial citrus plant with more varieties being developed in some parts of the USA, specifically Florida and Texas [52]. Sabinene is the main constituent of grapefruit essential oils from the USA (Duncan and Marsh; 42–59%) [53]. Other constituents include ocimenes, linalool, terpinen-4-ol, β-pinene, limonene, and myrcene [22, 54]. Grapefruit essential oil has been ascribed to several medicinal properties, such as antibacterial, antifungal, anticancer, anti-obesity, radical scavenging, and insecticidal effects [5, 32] effects.

3.7 Mandarin Coleopatra *Citrus* (*Citrus reshni*)

This species of the citrus genus originates from India and was brought to Florida from Jamaica around the mid-nineteenth century [22]. The essential oil from the peels and fresh leaves obtained by hydrodistillation is yellow. The fruit has an acidic flavor and a red–orange color with a thin and rough texture of the peels [55]. The fruit peel has limonene as the major component (93.6%) and others like myrcene, sabinene, and linalool are also present in appreciable quantities. The leaves have sabinene (49.7%) as the main constituent, followed by linalool and beta ocimene [56]. *Citrus reshni* essential oil has been reported to exhibit anti-inflammatory, antimicrobial [57], and antiviral [58] activities.

3.8 Yuzu *citrus* (*Citrus junos* Siebold ex Tanaka)

Citrus junos is a small tree of the family Rutaceae that produces a yellow-golden colored fruit from which essential oil is obtained due to the sweet flavor. Yuzu is a Northeast Asian citrus plant that is believed to have originated from China and was brought to Japan in the tenth century [59, 60]. *C. junos* are grown in China, Korea, and Japan, and are mainly used in the food industry in the production of teas, wines, and juices [61]. The major compounds of yuzu essential oil are determined using gas chromatography–olfactometry, and recent studies revealed components of yuzu essential oil such as terpene hydrocarbons and their derivatives [62]. It has been used as traditional medicine in Japan for aromatherapy and also shows neuroprotective, anti-obesity, anticancer, anti-inflammatory, and radical scavenging [5, 32, 63] activities.

3.9 Kumquat *citrus* (*Citrus japonica*)

Kumquats (*C. Japonica*) is a citrus plant commonly grown in southern parts of China for its fruits [64]. This citrus plant produces edible fruit which is normally eaten together with the peels. It is characterized by a sweet aroma attributed to the presence of flavonoids and terpenoids [65]. The essential oils extracted by hydro-distillation are rich in flavonoids [64]. The volatile constituents of kumquat essential oil are sesquiterpenes, terpenes, alcohols, ketones, aldehydes, and esters, and the major component is limonene (93%) [65]. The volatile and semi-volatile compounds found in citrus essential oil represent 85–99% of the entire oil fraction, which accounts for about 200 [66]. Compounds most frequently reported in citrus essential oils are hydrocarbon, mono-and sesquiterpenes, aliphatic and olefinic C6–C12 non-terpene aldehydes, alcohols, ketones, esters, and acids, along with several aromatic compounds [66]. Modification of the chemical profile of the essential oil may be altered by the extraction method used, which could affect its biological properties. Some of its biological properties include anticancer, radical scavenging, and antibacterial and antifungal [5, 32] effects.

3.10 Mandarin orange (*Citrus* reticulata Blanco)

Mandarin (*Citrus reticulata Blanco*) citrus is a small fruit tree or shrub that grows up to an average height of 20 feet and it is believed to originate from India and China [67]. *C. reticulata* have glossy leaves with aromatic flowers and bear small light-yellow sweet-scented fruits that are easily detached [68, 69]. It is popularly referred to as 'tangerine' in most parts of the world and its fruit is tasty and eaten freshly. The fruits of *C. reticulata* have rich reserves of vitamins C, vitamin B1-B3, beta-carotene, folate, potassium, and magnesium minerals [70]. Aside from the fruits, the leaves, flowers, and seeds of the plant have been ascribed with medicinal properties such as anti-inflammatory, antioxidant, anticancer, anti-emetic, pain relieving, and laxative effects [71, 72]. The essential oil of *C. reticulata* has been reported to have antibacterial, antifungal, antiparasitic, and anti-cancer [32, 71] effects. The biological properties of *C. reticulata* have been attributed to the constituents of its essential oil such as limonene, β-pinene, myrcene, D-limonene, citropten, linalool, α-thujene, α-terpene, camphene, α-pinene, 3-carene and tangerentin, and hesperidin [73, 74].

3.11 Overview of *citrus* essential oils extraction and detection methods

Citrus essential oils are normally synthesized as secondary metabolites stored within oil sacs found in peels, leaves, cuticles, and seeds [75]. These essential oils are extracted from the storage parts of the plant and purified using different extraction methods and techniques deemed efficient. The conventional methods of extraction for CEOs include solvent extraction, cold-pressing or hand pressing, simple distillation, steam distillation, and hydro-distillation methods [2]. These conventional methods are mostly time-consuming and involve high temperatures and harmful solvents, which often lead to reduced yield, loss of volatile compounds, and reduced quality (Fig. 1) [76]. New and innovative extraction methods and techniques have gained attention in recent times due to the low cost of energy and reduced carbon dioxide emissions. Due to the shortcomings of the conventional methods of extracting CEOs, pharmaceutical, food, and chemical industries and research scientists are working assiduously to develop novel extraction techniques that are efficient, safe, sustainable, energy-efficient, and time-saving. These new methods will increase extraction efficiency by reducing the loss of volatile compounds and waste generation while requiring less energy (heat), and increasing yield and quality (Fig. 1) [2, 77]. Some of the new and efficient extraction methods include microwave-assisted steam distillation (MASD), Microwave hydro-diffusion and Gravity (MHG), ultrasound-assisted extraction (UAE), and supercritical fluid extraction methods [78]. These new methods are termed "green extraction methods" due to the reduced emission of carbon dioxide (CO_2) and lower energy consumption, hence making them eco-friendly [79]. These newly developed methods and techniques are meant to achieve maximum extraction of the CEOs and their vital compounds in high quantities while reducing cost and pollution [77]. Currently, the MASD and UAE methods are reportedly the most efficient methods for the extraction of CEOs. After extraction of Citrus essential oils, the oil is subjected to a purification process to remove certain waste to increase the quality and enrich the concentration of targeted compounds. Chromatography methods are mostly used in the purification process. The major techniques are column chromatography, high-performance liquid chromatography (HPLC), and high-speed counter-current chromatography (HSCC) [80]. Also, some solvent combinations are used to enhance the purification processes, including chloroform and methanol, hexane and n-butanol or ethyl acetate, and butanol and water mixtures [77]. Purified CEOs containing the desired phytochemicals are detected and quantified using various methods such as mass spectroscopy (MS), gas chromatography-mass spectrometry (GC–MS), HPLC, nuclear magnetic resonance (NMR), UV-ultraviolet, ultra-high performance liquid chromatography time-of-flight mass spectrometry (UHPLC-ToF–MS), Field-emission scanning electron microscopy (FESEM), and attenuated total reflection Fourier-transform infrared spectroscopy (ATR-FTIR) (Table 1) [2, 77].

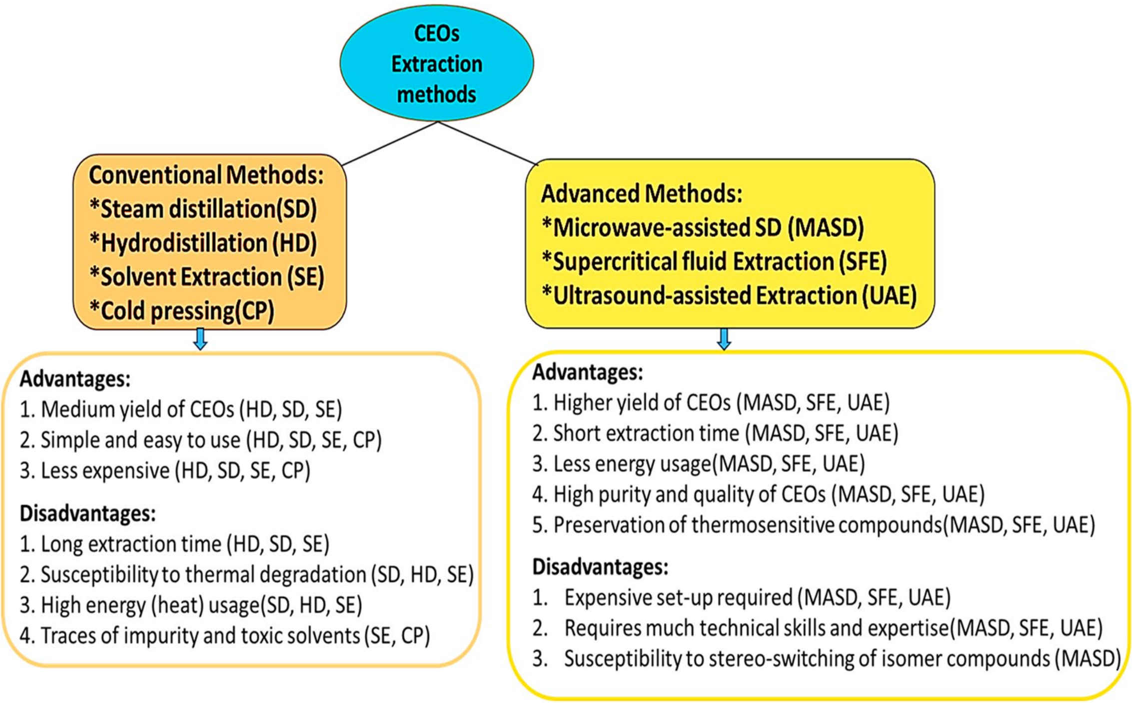

Fig. 1 a figure showing the advantages and disadvantages of conventional and advanced methods of extraction of citrus essential oils (CEOs)

Table 1 Ten selected citrus species and the methods of extraction and purification of their essential oils

Citrus species	Extraction method	Plant part	Purification/detection method	References
C. aurantifolia (lime)	Steam Distillation (SD)	Fruit, Epicarps, Flavedo, peels, leaves	GC, GC/MS	[35, 88–90, 99, 232, 233]
	Hydrodistillation (HD)/HD Clevenger apparatus	Peels, fruits, leaves, pomaces	GC/MS, UV–VIS, GC-FID	[37, 90, 106, 119, 121, 133, 150, 234–241]
	Hand/Mechanical Pressing	Pericarp	GC–MS	[168, 242]
	Microwave-assisted Steam Distillation (MASD)	Peels, leaves	GC–MS	[106, 243]
	Solvent/Maceration extraction	Peels	FTIR, GC-O, GC–MS	[183, 192]
	Microwave hydro-diffusion and Gravity (MHG)	Fruits peels	GC, GC–MS	[161]
	Supercritical fluid extraction, SC-CO_2	Leaves	GC–MS, FTIR, UV	[207]
	Ultrasound-assisted Extraction (UAE)	Fruit peels	HPLC	[227]
C. aurantium (Bitter orange)	Steam distillation (SD)	Fruits, peels, blossoms	GC-FID, GC–MS, HS-GC–MS	[94, 95, 228, 244–247]
	Hydrodistillation (HD)/ HD Clevenger apparatus	Peel, Flower, leaves, blossoms	GC–MS, GC-FID, GC–MS-LRI, CPG-MS	[129, 152, 230, 240, 241, 246–251]
	Microwave-assisted hydrodistillation (MA-HD)	Peels	CGP-MS	[152]
	Microwave-assisted steam distillation (MASD)	Peels	GC–MS	[94, 252]
	Ultrasound-assisted Extraction (UAE)	Buds	GC–MS	[228]
	ultrasonic-assisted headspace solid phase micro-extraction (UA-HS-SPME)	Flower	GC–MS	[230]
	Cold pressing	Fruit cortex	GC–MS	[164, 168]
	Solvent-free microwave-assisted extraction (SFME)	Blossoms	GC-FID, GC–MS	[247]
	Ohmic-assisted hydrodistillation (OAHD**)**	Blossoms	GC-FID, GC–MS	[247]
	Supercritical CO_2(SC-CO_2)	Peels	GC-FID/MS	[206]

Table 1 (continued)

Citrus species	Extraction method	Plant part	Purification/detection method	References
C. bergamia (bergamot)	Steam Distillation (SD)	Fruits	GC–MS	[96]
	Hydrodistillation (HD)/HD-Clevenger apparatus	Peels	GC-FID, GC–MS	[130, 241, 253]
	Headspace solid-phase microextraction (HS-SPME)	Peels	GC–MS	[231]
	Supercritical CO_2(SC-CO_2)	Peels	GC-FID/MS, GC–MS	[48, 206]
	Supercritical fluid extraction (SFE)	Seeds	GC	[208]
	Solvent/Soxhlet Extraction	Seed, peels	GC, LC–MS	[208, 254, 255]
	Hand/Cold pressing	Peels, fruits	GC,GC–MS, LCMS-IT-ToF, GC-FID, GC-C-IRMS, enantio-GC, MDGC, HPLC and HPLC–MS-IT-ToF	[165, 168, 240, 256–259]
	ultrasound-assisted hydrodistillation (UAHD)	Peels	GC–MS	[231]
C. sinensis (Sweet orange)	Steam Distillation (SD)	Peels	GC, GC-FID, GC–MS	[86, 90–92, 99, 101, 107, 194]
	Microwave-assisted steam distillation (MASD)	Peels	GC-FID, GC–MS	[86, 194, 252]
	Microwave hydro-diffusion and Gravity (MHG)	Peels	GC–MS	[161]
	Hydrodistillation (HD)/HD Clevenger apparatus	Peels	GC, GC–MS HPLC, FTIR, GC-FID FESEM, CPG-MS	[92, 107, 122–128, 134, 144, 146, 152, 224, 241, 251, 260, 261]
	Cold pressing	Peels	GC-FID, GC, GC–MS	[122, 163, 165, 166, 168, 169, 176, 259, 262]
	Microwave-assisted hydrodistillation (MA-HD)	Peels	GC, GC–MS, CPG-MS, DRIFT	[127, 152, 153, 196, 197]
	Salt-assisted extraction hydrodistillation (S-HD)	Peels	GC–MS	[156]
	Enzymes-assisted hydrodistillation (E-HD)	Peels	GC–MS, GC	[155, 156]
	Solvent free Microwave extraction (SFME)	Peels	GC–MS, GC-FID, DRIFT	[122, 123, 156, 201]
	Microwave-assisted solvent extraction (MASE)	Peels	GC–MS	[200]
	Ionic liquid-based microwave-assisted extraction (MAE-IL)	Peels	GC–MS	[199]
	Solvent /Soxhlet Extraction	Peels	GC, GC–MS, FTIR	[92, 185–187, 260]
	Ultrasound-assisted extraction (UAE)	Peels, pulp	GC, GC–MS, HPLC, FTIR	[156, 224, 260, 263]
	Supercritical CO_2(SC-CO_2)	Peels	GC-FID/MS	[206]

Table 1 (continued)

Citrus species	Extraction method	Plant part	Purification/detection method	References
C. limon (Lemon)	Steam distillation (SD)/SD Clevenger apparatus	Peels, rind, leaves, fruits, epicarps	GC, GC-FID, GC–MS	[86, 90, 93, 98–103, 232, 244, 264]
	Microwave-assisted steam distillation (MASD)	Peels	GC-FID, GC–MS	[86, 252]
	Cold/Hand pressing	Peels, seeds, leaf	GC, GC–MS, GC-FID, RP-HPLC, GC–C-IRMS	[165, 167–171, 252, 259]
	Solvent extraction/Soxhlet Extraction	Peels, leaves	GC–MS	[136, 188, 189]
	Microwave hydro-diffusion and Gravity (MHG)	Peels	GC–MS	[161]
	Hydrodistillation (HD)/HD Clevenger apparatus	Peels, zest, leaves, aerial parts	GC, GC–MS, CPG-MS, GC-FID, FTIR, DRIFT	[120, 128, 131, 132, 134–138, 140–145, 152, 158, 189, 195, 239, 241, 251, 252, 265, 266]
	microwave-assisted hydrodistillation (MAHD)	Fruit peels	GC–MS, CPG-MS	[120, 152, 153, 158, 195]
	Plasma and microwave-assisted hydrodistillation (PAHD)	Peels	GC–MS	[158]
	Ohmic heating-assisted hydrodistillation (OH-HD)	Peels	GC, FTIR	[151]
	Solvent-free microwave extraction (SFME)	Peels, leaves	GC–MS, DRIFT	[120, 195, 201, 265]
	Supercritical fluid extraction (SFE)/SC-CO_2	Peels and leaves	GC–MS, GC-FID	[136, 145]
	Simultaneous distillation extraction at reduced pressure (V-SDE) and Solid-phase microextraction	Peels	MDGC-MS	[267]
C. junos (Yuzu)	Soxhlet/ Solvent extraction	Peels, pomace	GC–MS	[190]
	Hexane Soxhlet with Supercritical CO_2 extraction	Seeds	GC–MS, GC-FID	[209]
	Supercritical CO_2(SC-CO_2)	Peels	GC–MS, GC-FID	[59, 210, 211]
	Cold pressing	Peels	GC–MS	[174, 175, 268]

Table 1 (continued)

Citrus species	Extraction method	Plant part	Purification/detection method	References
C. paradisi (Grapefruit)	Steam distillation (SD)	Peels	GC–MS	[101]
	Solvent/Soxhlet extraction	Peels	GC, GC–MS	[186, 269]
	Microwave-assisted steam distillation (MASD)	Peels	GC–MS	[252]
	Hydrodistillation (HD)/HD Clevenger apparatus	Peels, Zest, rind	GC–MS, FTIR	[54, 134, 139, 142, 146, 147, 157, 202, 241, 261, 270, 271]
	Enzyme-assisted hydrodistillation (E-HD)	Peels	GC	[155]
	Microwave-assisted hydrodistillation (MAHD)	Peels	GC-FID/GC–MS	[157]
	Microwave hydro-diffusion and gravity (MHG)	Peels	GC–MS	[161]
	Cold/Hand pressing	Peels	GC, GC–MS	[139, 165, 169, 172]
	Solvent-free microwave extraction (SFME)	Peels	DRIFT, GC–MS	[201, 202]
C. reticulata (Mandarin)	Steam distillation (SD)/ SD Clevenger apparatus	Fruits, rinds, peels	GC-FID, GC–MS	[86, 101, 103, 244]
	Hydrodistillation (HD)/HD Clevenger apparatus	Peel, leaf, Zest	GC–MS, NMR, GC-FID, HPTLC-densitometry	[56, 142, 146, 149, 241, 261, 272–275]
	Hand/mechanical pressing	Peels	GC, GC–MS	[72, 165, 168]
	Microwave-assisted steam distillation (MASD)	Peels	GC-FID	[86]
	Microwave-assisted hydrodistillation (MAHD)	Peels	GC–MS	[67]
	Ultrasound-assisted extraction (UAE)	Fruit peels	HPLC, FTIR	[227, 276, 277]
Kumquat *(C. japonica)*	Hydrodistillation (HD)/HD-Clevenger apparatus	Peels, leaves	GC–MS, GC-FID, NMR	[64, 154, 191, 198, 229, 251, 253, 278–281]
Fortunella crassifolia	Steam Distillation	Fruits	GC–MS, HPLC	[104]
Fortunella japonica	Microwave-assisted hydrodistillation (MAHD)	Leaves	GC–MS, C NMR	[154]
C. japonica	Solvent extraction	Peels	GC, GC–MS	[191, 282]

Table 1 (continued)

Citrus species	Extraction method	Plant part	Purification/detection method	References
F. Margarita	Vacuum hydrodistillation	Peels	GC–MS	[229]
	Cold pressing	Peels	HS-SPME/GC	[105]
	Hydrodistillation (HD) / Clevenger apparatus	Peels, leaves	GC–MS	[283, 284]
	Steam distillation	Peels	HS-SPME/GC	[105]
	Ultrasound-assisted vacuum hydrodistillation (UAV-HD)	Peels	GC–MS	[229]
	Ultrasound-assisted hydrodistillation (UA-HD)	Peels	GC–MS	[198]
	Microwave-assisted hydrodistillation (MA-HD)	Peels	GC–MS	[198]
	Supercritical CO_2 extraction	Peels	GC–MS	[191, 212]

4 Methods of extraction of *citrus* essential oils (CEOs)

4.1 Steam distillation (SD)

This is one of the most common methods used in the large-scale production of various essential oils and about 90% of essential oils are extracted with this technique [81]. This method is a modification of a normal distillation system where a generated steam interacts with the plant material to release the targeted substance, and it is suitable for extracting heat-sensitive compounds and substances [82]. It involves the use of a steam generator flask, a distilling flask, a condenser, and a receiving vessel. This method has been employed officially for extracting various citrus essential oils because of its high efficiency and is also economical compared to other methods [83, 84]. The method involves feeding the plant materials, mostly leaves or fruit peels into the chamber (a perforated plate) above the steam inlet without exposing the plant material to a direct heat source but rather to vapor from the boiler [85]. This is followed by condensation in a condenser which separates the oily molecules from water vapor [86]. Steam distillation was applied in the extraction of essential oils from the chopped leaves or peels of lemon, mandarin, and orange by passing a steam (1 kg/h; 96–100 °C) at 1.1 atm for about 3 h [87]. Steam distillation was slightly modified by preheating before the distillation and it gave a higher yield of essential oil from *C. sinensis* and *C. reticulata* at a percentage of 4.24% and 5.87% respectively, as compared to the conventional steam distillation which yielded 2.48% and 0.98% for *C. sinensis* and *C. reticulata* respectively [83]. The steam distillation method has also been used to extract essential oil from the peels, flavedo, and leaves of *C. aurantifolia*, *C. limon*, *C. aurantium*, *C. bergamia*, *C. limetta, C. reticulata, F. crassifolia, F. margarita, C. sinensis* and *C. aurantifolia* (Table 1) [86, 88–106]. A steam explosion method operating at high temperature and pressure was used to extract essential oil from the fruit peels of *C. sinensis* and was found to reduce extraction time by eightfold in comparison to a hydrodistillation method [107]. Even though this method gives a substantial yield of safe and quality essential oil from various citrus plant materials. The major setbacks of the steam distillation method are the vapour pressure and the thermal degradation of thermolabile compounds, longer extraction time, and high energy consumption, which have also been reported to induce partial hydroxylation [108, 109]. The disadvantages associated with this method have led to newly improved "green" extraction techniques such as ultrasound-assisted extraction (UAE), which was faster with increased quality compared to the conventional method [110]. Others like microwave-assisted extraction (MAE) and CO_2 supercritical extraction have also been more efficient than the old extraction methods [111, 112].

4.2 Hydrodistillation (HD)

This method is the most common method employed in the extraction of essential oil [113]. In this method, the plant material is placed in the water bath and boiled to the boiling point (mostly 100 °C) under atmospheric pressure. The mixture is then condensed by cooling, followed by separation of the mixture via decantation [114]. This method is efficient for plant materials with water-soluble and thermostable constituents at high boiling points, but very high temperatures could degrade heat-sensitive components, thus affecting the quality of the essential oil [115, 116]. HD is reported to be more efficient than other methods because it does not involve the use of chemical solvents, and thus the toxic effect of chemicals and the subsequent loss of volatile compounds during the removal of solvents is easily avoided [117]. In other studies, *C. aurantium*, *C. japonica, C. sinensis*, *C. aurantifolia*, grapefruit (*C. paradisi*), *F. margarita*, *C. reticulata*, kumquat (*F. margarita*), *C. bergamia* and lemon (*C. limon*) fruit peels and leaves and essential oils were extracted using hydrodistillation (Table 1) [74, 90, 92, 118–149]. In another study, *C. limon* peels and distilled water were placed in the HD with a Clevenger-type apparatus, and it was followed by condensation which separated the oily molecules from that of water vapour [120]. In a similar procedure, the fruit peels of *C. aurantifolia* and *C. limon* gave an average yield of 1.4% from 150 g of fruit peels [150]. The oven-dried peels of *C. reticulata, C. sinensis,* and *C. paradisi* yielded substantial quantities in the following ranges from 0.30–0.50 g/100 g, 0.24–1.07 g/100 g and 0.20–0.40 g/100 g, respectively, under the hydrodistillation method [118]. In a comparative study, the hydrodistillation method used for *C. sinensis* essential oil extraction produced oil that contained 10 to 13 main constituents which were absent in the steam explosion method. However, the steam explosion method was eight times faster than the hydrodistillation method [107].

The Ohmic heating-assisted hydrodistillation method was successfully used to co-extract essential oil and pectin from *C. limon* waste peels [151]. Several modifications of the traditional hydrodistillation method have led to decreased extraction time and enhanced extraction efficiency. These include turbo-hydro-distillation, ultrasound-assisted hydrodistillation (U-HD), enzyme-hydrodistillation (E-HD), micelle-hydrodistillation, and salt-hydrodistillation (S-HD). In a recent study, the microwave-assisted hydrodistillation (MA-HD) method was used to extract essential oils from the fruit peels of *C. aurantium, F. japonica, C. limon,* and *C. sinensis,* and the yield was almost twice the yield in the conventional hydrodistillation method [152–154]. Interestingly, another study reported that the enzyme-assisted hydrodistillation technique enhanced essential oil recovery yield from *C. paradisi, C. sinensis,* and *C. limonium* cv. colima and the extraction efficiency was between twofold to sixfold that of the conventional hydrodistillation method [155]. The microwave-assisted hydrodistillation (MAHD), ultrasound-assisted hydrodistillation (U-HD), enzyme-assisted hydrodistillation (E-HD), and salt-assisted hydrodistillation (S-HD) methods were used to extract essential oil from the peels of *C. sinensis* [127, 156]. In a comparative study, the fruit peels essential oil of *C. paradisi* was extracted through hydrodistillation (HD) and microwave-assisted hydrodistillation (MAHD) and the GC-FID/GC–MS analysis shows that MAHD possessed 28 major constituents as against 21 constituents in the HD [157]. Hydrodistillation (HD), microwave-assisted hydrodistillation (MAHD), and plasma and microwave-assisted hydrodistillation (PAHD) methods were used comparatively to extract essential oil from the peels of *C. limon*. The results from the study revealed that the plasma-assisted microwave pre-treatment (PAHD) and microwave-assisted hydrodistillation (MAHD) methods significantly improved the extraction yield by 149.34% and 58.28% as compared to hydrodistillation (HD) [158].

4.3 Cold pressing

Hand or cold pressing, also known as mechanical pressing, is one of the oldest traditional methods of extracting citrus essential oils in large quantities before the emergence of the use of scientific apparatus, methods, and techniques. The essential oil obtained by cold pressing is characterized by strong aroma properties, high nutritional value, and high levels of major constituents because it is free from heat and chemical treatment [159]. The cold pressing method is done manually by pressing the peel layers exposing the oil sacs. Followed by squeezing the oil out of the sacs into the form of a watery emulsion and it is centrifuged to obtain the separate essential oil [85, 160, 161]. In this method, citrus essential oils could also be squeezed from the fruit peels using machines at room temperature and subsequently, washed with cold water. Finally, the oil is then obtained by centrifugation [84]. Although mechanical or hand pressing is one of the traditional methods of extracting essential oils, it is not a preferred method due to the low yield compared to the steam and hydrodistillation methods [85]. However, cold pressing was employed in extracting essential oils from *C. aurantium, F. margarita, C. sinensis*, *C. junos*, *C. reticulata*, *C. limon*, *C. paradisi,* and *C. grandis* by pressing the follicular glands of citrus peels through mechanical maceration thus releasing their contents (Table 1) [23, 59, 105, 122, 139, 162–176]. This method is reported to be simple, rapid, environmentally friendly, and inexpensive compared to alternative methods [160]. Cold-pressed oils, aside from being safe, also have a characteristic aromatic fragrance which is the reason behind their wide application in the beverages, cosmetics, and pharmaceutical industries [177]. However, the cold pressing method is not suitable for plant materials with low essential oil content. Cold-pressed oils may also contain polyunsaturated fatty acids (PUFAs) and pro-oxidative components that reduce their oxidative stability and shelf-life [178].

4.4 Solvent extraction (SE)

This is the oldest method used to obtain a crude extract from plants and also has been used in essential oil extraction via the principle of solubilization of compounds present in the cells of various plant materials using an appropriate solvent [179]. Essential oils extracted under this method normally involve dissolving the plant material in a specific solvent and the oil is obtained by subjecting it to evaporation followed by filtration and distillation [114]. Solvents like chloroform, ethanol, acetone-hexane, and ethyl acetate have been used in the extraction of various essential oils including citrus essential oils [83, 180, 181]. Thus, the fruit peels of *C. reticulata* were successively extracted with hexane, chloroform, and acetone using a Soxhlet extractor [180]. In another study, ethyl acetate was employed in extracting CEOs [182]. Citrus essential oil was extracted from fruit peels of lime (*C. aurantifolia*) using ethanol, hexane, and water in a maceration solvent and Soxhlet extraction methods [183]. Also, the solvent extraction method gave a substantial yield of essential oil from the peels of *C. medica* compared to the hydrodistillation method [184]. In addition, the essential oil was extracted from fruit peels and leaves of *C. sinensis, C. junos, F. margarita, C. limon,* and *C. paradisi* by Soxhlet solvent extraction method using hexane, n-hexane, and ethanol (Table 1) [92, 136, 185–191]. *Citrus aurantifolia* Swingle fruit peels were extracted with pentane: ether (1:1) solvent extraction method and over 50 volatile compounds were identified using

GC-O and GC–MS [192]. Hexane was used to extract essential oil from the fruits of *Citrus limetta* which gave a higher yield than steam distillation. However, the oil obtained contained pigments, waxes, and polysaccharides, hence reducing its quality [97]. The main problem associated with this method is the toxic effects of some of the solvents such as benzene and dichloromethane commonly used, coupled with the loss of certain volatile compounds during the removal of the solvents [193]. Thus, the method also requires heating the solvent to 100◦C and however, not suitable for extracting volatile and thermolabile components [114].

4.5 Microwave-assisted steam distillation (MASD)

This method is a modified form of steam distillation method that has been used in some studies to increase the yield extraction of CEOs and preserve specific components that are susceptible to destruction by direct steam. The main principle of this method relied on the switch in polarity from water-generated steam to wave-generated steam, where the normal heating source (electric heating cap) has been replaced with a microwave [179]. The MASD works through fast rupture of the cell wall, thus releasing the content of the cytoplasm using strong microwaves [4]. The method is said to be environmentally friendly for the extraction of essential oils from different plant materials [111]. Essential oils from orange (*C. sinensis*), lemon (*C. limon*), mandarin (*C. reticulata*) obtained by MASD yielded 1.150%, 1.115%, and 0.940% respectively [86]. This method has been used to extract essential oil from the peels of *C. limon*, *C. reticulata*, *C. sinensis* fruits [86, 194]. Also, the microwave-assisted hydrodistillation method was successfully used to extract essential oil from the fruit peels of *C. reticulata* and the GC–MS analysis revealed that the oil contained limonene, β-myrcene, and sabinene in a proportion of 97.68%, 1.39% and 0.12% respectively [67]. Another study reported that MASD has a shorter extraction time (about 6 min) and yields much higher quality essential oil with strong aromatic properties from *C. sinensis* peels at a microwave power of 500W compared to the traditional steam distillation method [194]. The solvent-free microwave extraction method was employed in the essential of essential oil from the fruit peels of *C. aurantium*, *C. sinensis,* and *C. limon* (Table 1) [94, 156, 195]. Microwave-assisted steam distillation has higher efficiency than steam distillation because it shortens extraction time and enhances the process of extraction while preserving the components of the oil in higher quantities [4]. The shortcoming reported in this method had to do with the use of microwaves since the waves are believed to result in chemical stereo-switching from one isomer to another in the compounds found in the essential oils, thus altering certain key components to other forms [179]. Besides MASD, other microwave-assisted extraction methods used in the extraction of *C. sinensis* essential oils include hydro-diffusion and gravity (MHG) [161]. The microwave-assisted hydrodistillation (MA-HD) method was employed in the extraction of essential oils from *C. limon*, *F. margarita*, *C. sinensis,* and *C. medica* [120, 184, 195–198]. Ionic liquid-based microwave-assisted extraction (MAE-IL), solvent-free microwave extraction (SFME), and microwave-assisted solvent extraction (MASE) were successfully used to extract essential oils from the peels of *Citrus sinensis* [122, 123, 156, 199, 200]. Solvent-free microwave-assisted extraction (SFME) has been employed in extracting essential oil from the peels of *C. limon, C. sinensis,* and *C. paradisi* and the yield was higher than that of the industrial extraction methods [201, 202]. Methods like ultrasonic microwave-assisted extraction, vacuum microwave-assisted extraction, and microwave-assisted Soxhlet extraction have not been used to extract citrus essential oils (CEOs) yet.

4.6 Supercritical fluid extraction (SFE)

This is one of the complex methods of extracting essential oil from plant materials commonly used in food, cosmetics, and pharmaceuticals [109, 203]. The method operates based on using harmless gases, for example, carbon dioxide (CO_2), propane, butane, and others at their supercritical stage (at high pressure) to extract essential oils [179]. These non-toxic solvents, including carbon dioxide (CO_2), propane, butane, and others are used to extract essential oil from plant material at low temperatures and high pressure, hence, avoiding thermal destruction or breakdown of volatile constituents [204]. Carbon dioxide (CO_2) solvent is commonly used in the supercritical fluid extraction (supercritical carbon dioxide, SC-CO_2) of citrus essential oil because of its characteristic low surface tension, high diffusivity, viscosity, and low critical temperature (304 K) [205]. Moreover, the method is termed a 'green' technology application and has been efficiently used to extract some CEOs, specifically, SC-CO_2 was used to obtain quality essential oils from, *C. limon*, *C. aurantifolia, C. bergamia, C. aurantium, F. margarita, C. sinensis, C. sphaerocarpa,* and *C. junos* essential oils (Table 1) [109, 136, 145, 191, 205–212]. The SFE method is superior to other methods because it is toxic-free, nonflammable, and requires low to moderate temperature and pressure [213]. However, the main problem associated with the use of SC-CO_2 is that it has a low polarity which affects the extraction of polar compounds (analytes).

Hence, certain modifications have to be made through the addition of polar modifying solvents like methanol or ethanol to enhance solution power and subsequently improve extraction efficiency [203]. Moreover, the SC-CO_2 extraction process involves the pretreatment of plant material that includes milling and drying, thus, exposing the plant material to air oxidation and enzymatic denaturation [109]. Furthermore, this method is very expensive and has slow extraction kinetics due to the difficulty of using mechanical vibrations [214].

4.7 Ultrasound-assisted extraction (UAE)

The use of ultrasound waves for the extraction of phytochemicals has gained attention in recent times due to its efficiency and eco-friendly nature. The ultrasound-assisted extraction (UAE) method has been successfully used for lipids, proteins, and bioactive compounds such as polyphenols, berberine, and citrus essential oils [215, 216]. In the UAE extraction, the plant material such as the leaves, flowers, fruit peels, and seeds are soaked in water and other solvents like ethanol, and the ultrasound is then applied [217]. The UAE works on the principle of acoustic cavitation which involves the production, expansion, and rupturing of bubbles filled with gaseous vapor in liquid which facilitates the disruption and permeation of the cell wall of the plant tissue or extraction material [218, 219]. This cavitation process induces turbulence and current circulation in the liquid, resulting in the compression and refraction of the gas-filled bubbles, thus enhancing the rate of extraction at ambient temperature and pressure [220, 221]. This green extraction method has become one of the choicest methods in most industries because of its associated benefits, which include reduced energy consumption, heat production, solvent usage, waste generation, processing time, and increased yield and quality [222, 223]. This clean extraction method has been applied in the extraction of citrus essentials oils, including *C. sinensis*, *C. limetta* (sweet lime), *C. aurantium*, *F. margarita*, *C. aurantifolia*, and *C. reticulata* (Table 1) [3, 198, 216, 224–229]. Ultrasound and microwave methods have been used simultaneously as one method referred to as the ultrasonic microwave extraction method to extract essential oils. Ultrasonic microwave-assisted hydrodistillation extraction (UMHD) was used to extract essential oil from the peels of *Citrus medica* and *Fortunella margarita* [184]. The study revealed that the UMHD method and the hydrodistillation method had similar essential oil composition, however, the UMHD increased the extraction yield and reduced extraction time. Ultrasonic-assisted headspace solid phase micro-extraction (UA-HS-SPME) has been used to extract essential oil from *C. aurantium* and *C. bergamia* [230, 231]. Another study used ultrasound-assisted hydrodistillation (UAHD) to extract essential oil from the fruits of *Citrus bergamia* which gave an extraction yield of 0.48%, which was estimated to be 118% higher than the yield from hydrodistillation (HD) [231].

5 Conclusion

Over the years there has been a significant improvement in techniques employed in the extraction of citrus essential oils (CEOs). The traditional extraction methods are associated with limitations such as long extraction time, high energy consumption, CO2 emissions, degradation of major essential oil constituents, and reduction in oil yield and quality. However, technological advancement has helped CEO extraction through the development of innovative, efficient, and eco-friendly extraction techniques. As new methods continue to evolve each day, techniques such as ultrasound, microwaves, and supercritical fluid extraction have demonstrated promising extraction efficiency and could be used for large-scale production of quality CEOs. This present review gives an in-depth exposition of the extraction techniques, their advantages, and disadvantages, as well as the innovations and modifications of the current techniques developed for the extraction of citrus essential oils (CEOs). This review, therefore, brings to the forefront the most recent efficient extraction techniques and modifications for CEOs and provides a well-organized and informative extraction choice for researchers and industries.

Authors contributions AB and CKA wrote the main manuscript text and CO and CKA reviewed the manuscript.

Funding This research did not receive funding from any public or non-profit agencies.

Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

References

1. Wu GA, Terol J, Ibanez V, López-García A, Pérez-Román E, Borredá C, Domingo C, Tadeo FR, Carbonell-Caballero J, Alonso R. Genomics of the origin and evolution of Citrus. Nature. 2018;554(7692):311–6.
2. Bora H, Kamle M, Mahato DK, Tiwari P, Kumar P. Citrus essential oils (CEOs) and their applications in food: An overview. Plants. 2020;9(3):357.
3. Nishad J, Saha S, Kaur C. Enzyme-and ultrasound-assisted extractions of polyphenols from Citrus sinensis (cv. Malta) peel: a comparative study. J Food Process Preserv. 2019;43(8):14046.
4. Mahato N, Sharma K, Koteswararao R, Sinha M, Baral E, Cho MH. Citrus essential oils: extraction, authentication and application in food preservation. Crit Rev Food Sci Nutr. 2019;59(4):611–25.
5. Brah AS, Armah FA, Obuah C, Akwetey SA, Adokoh CK. Toxicity and therapeutic applications of citrus essential oils (CEOs): a review. Int J Food Prop. 2023;26(1):301–26.
6. G. Dugo, A. Di Giacomo, Citrus: the genus citrus, CRC Press (2002).
7. Ferhat MA, Meklati BY, Chemat F. Comparison of different isolation methods of essential oil from Citrus fruits: cold pressing, hydrodistillation and microwave 'dry'distillation. Flavour Fragr J. 2007;22(6):494–504.
8. Mustafa NEM. Citrus essential oils: current and prospective uses in the food industry. Recent Patents Food Nutr Agric. 2015;7(2):115–27.
9. Berger RG. Flavours and fragrances: chemistry, bioprocessing and sustainability. Springer, Cham: Springer Science & Business Media; 2007.
10. Brooks EJ, Wilson DR. Reducing stress and anxiety during pregnancy. Int J Childbirth Educ. 2019;34(1):16.
11. Palazzolo E, Laudicina VA, Germanà MA. Current and potential use of citrus essential oils. Curr Org Chem. 2013;17(24):3042–9.
12. Shaw PE. Review of quantitative analyses of citrus essential oils. J Agric Food Chem. 1979;27(2):246–57.
13. Muriel-Galet V, Cran MJ, Bigger SW, Hernández-Muñoz P, Gavara R. Antioxidant and antimicrobial properties of ethylene vinyl alcohol copolymer films based on the release of oregano essential oil and green tea extract components. J Food Eng. 2015;149:9–16.
14. Nannapaneni R, Chalova VI, Crandall PG, Ricke SC, Johnson MG, O'Bryan CA. Campylobacter and Arcobacter species sensitivity to commercial orange oil fractions. Int J Food Microbiol. 2009;129(1):43–9.
15. Putnik P, Bursać Kovačević D, Režek Jambrak A, Barba FJ, Cravotto G, Binello A, Lorenzo JM, Shpigelman A. Innovative "green" and novel strategies for the extraction of bioactive added value compounds from citrus wastes—A review. Molecules. 2017;22(5):680.
16. Jha AK, Sit N. Extraction of bioactive compounds from plant materials using combination of various novel methods: a review. Trends Food Sci Technol. 2022;119:579–91.
17. Mahawer SK, Himani SA, Kumar R, Prakash O. Extractions Methods and Biological Applications of Essential Oils, Essential Oils: Advances in Extractions and Biological Applications. United Kingdom: IntechOpen London; 2022.
18. Hodgson R. History, world distribution, botany and varieties. The Citrus Industry. 1967;1:431–591.
19. Favela-Hernández JMJ, González-Santiago O, Ramírez-Cabrera MA, Esquivel-Ferriño PC, Camacho-Corona MDR. Chemistry and pharmacology of citrus sinensis. Molecules. 2016;21(2):247.
20. Abbate L, Tusa N, Del Bosco SF, Strano T, Renda A, Ruberto G. Genetic improvement of Citrus fruits: New somatic hybrids from Citrus sinensis (L.) Osb. and Citrus limon (L.) Burm. F. Food Res Int. 2012;48(1):284–90.
21. Aydeniz-Guneser B. Cold pressed orange (Citrus sinensis) oil. Cold Pressed Oils: Elsevier; 2020. p. 129–46.
22. Osman A. Citrus Oils, Fruit Oils: Chemistry and Functionality. Cham: Springer; 2019.
23. Njoroge SM, Koaze H, Karanja PN, Sawamura M. Essential oil constituents of three varieties of Kenyan sweet oranges (Citrus sinensis). Flavour Fragr J. 2005;20(1):80–5.
24. Smith DC, Forland S, Bachanos E, Matejka M, Barrett V. Qualitative analysis of citrus fruit extracts by GC/MS: an undergraduate experiment. Chem Educ. 2001;6(1):28–31.
25. Etebu E, Nwauzoma A. A review on sweet orange (Citrus sinensis L Osbeck): health, diseases and management. Am J Res Com. 2014;2(2):33–70.
26. Milind P, Dev C. Orange: range of benefits. Int Res J Pharm. 2012;3(7):59–63.
27. Dongre P, Doifode C, Choudhary S, Sharma N. Botanical description, chemical composition, traditional uses and pharmacology of Citrus sinensis: An updated review. Pharmacol Res Modern Chinese Med. 2023;8: 100272.

28. Kirbaslar FG, Kirbaslar SI. Composition of cold-pressed bitter orange peel oil from Turkey. J Essent Oil Res. 2003;15(1):6–9.
29. Suntar I, Khan H, Patel S, Celano R, Rastrelli L, An overview on Citrus aurantium L.: its functions as food ingredient and therapeutic agent, Oxidative medicine and cellular longevity 2018 2018.
30. Boussaada O, Chemli R. Seasonal variation of essential oil composition of Citrus aurantium L. var. amara. J Essent Oil Bear Plants. 2007;10(2):109–20.
31. de Moraes Pultrini A, Galindo LA, Costa M. Effects of the essential oil from Citrus aurantium L. in experimental anxiety models in mice. Life Sci. 2006;78(15):1720–5.
32. Dosoky NS, Setzer WN. Biological activities and safety of Citrus spp. essential oils. Int J Mol Sci. 2018;19(7):1966.
33. Gruenwald J, Brendler T, Jaenicke C, PDR for Herbal Medicines. 2 [sup] nd ed, Montvale, New Jersey, USA: Medical Economics Company 2000: 497–500.
34. Başer KHC, Demirci F. Chemistry of essential oils, Flavours and Fragrances: Chemistry, Bioprocessing and Sustainability, edited by Berger RG. New York: Springer; 2007. p. 43–86.
35. Adokoh CK, Asante D-B, Acheampong DO, Kotsuchibashi Y, Armah FA, Sirikyi IH, Kimura K, Gmakame E, Abdul-Rauf S. Chemical profile and in vivo toxicity evaluation of unripe Citrus aurantifolia essential oil. Toxicol Rep. 2019;6:692–702.
36. Narang N, Jiraungkoorskul W. Anticancer activity of key lime, Citrus aurantifolia. Pharmacogn Rev. 2016;10(20):118.
37. Al-Aamri MS, Al-Abousi NM, Al-Jabri SS, Alam T, Khan SA. 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. 2018;13(2):108–12.
38. Hsouna AB, Halima NB, Smaoui S, Hamdi N. Citrus lemon essential oil: chemical composition, antioxidant and antimicrobial activities with its preservative effect against Listeria monocytogenes inoculated in minced beef meat. Lipids Health Dis. 2017;16(1):146.
39. Sun Y, Chen S, Zhang C, Liu Y, Ma L, Zhang X. Effects of sub-minimum inhibitory concentrations of lemon essential oil on the acid tolerance and biofilm formation of Streptococcus mutans. Arch Oral Biol. 2018;87:235–41.
40. Alfonzo A, Martorana A, Guarrasi V, Barbera M, Gaglio R, Santulli A, Settanni L, Galati A, Moschetti G, Francesca N. Effect of the lemon essential oils on the safety and sensory quality of salted sardines (Sardina pilchardus Walbaum 1792). Food Control. 2017;73:1265–74.
41. Al-Qudah TS, Zahra U, Rehman R, Majeed MI, Sadique S, Nisar S, Tahtamouni R, Tahtamouni RW. Lemon as a source of functional and medicinal ingredient: a review. Int J Chem Biochem Sci. 2018;14:55–61.
42. Sohi S, Shri R. Neuropharmacological potential of the genus Citrus: a review. J Pharmacogn Phytochem. 2018;7(2):1538–48.
43. Weimer P, Moura JGL, Mossmann V, Immig ML, de Castilhos J, Rossi RC. Citrus aurantiifolia (Christm) Swingle: Biological potential and safety profile of essential oils from leaves and fruit peels. Food Biosci. 2021;40: 100905.
44. Jain S, Arora P, Popli H. A comprehensive review on Citrus aurantifolia essential oil: its phytochemistry and pharmacological aspects. Braz J Nat Sci. 2020;3(2):354–354.
45. Rapisarda A, Germanò MP. Citrus× bergamia Risso & Poiteau: Botanical Classification, Morphology, and Anatomy. Citrus bergamia: CRC Press; 2013. p. 34–49.
46. Navarra M, Mannucci C, Delbò M, Calapai G. Citrus bergamia essential oil: from basic research to clinical application. Front Pharmacol. 2015;6:36.
47. Sawamura M, Onishi Y, Ikemoto J, Tu NTM, Phi NTL. Characteristic odour components of bergamot (Citrus bergamia Risso) essential oil. Flavour Fragr J. 2006;21(4):609–15.
48. Bonaccorsi I, Trozzi A, Cotroneo A, Dugo G. Composition of industrial bergamot petitgrain produced in Calabria. J Essent Oil Res. 2013;25(5):359–63.
49. Forlot P, Pevet P. Bergamot (Citrus bergamia Risso et Poiteau) essential oil: Biological properties, cosmetic and medical use A review. J Essent Oil Res. 2012;24(2):195–201.
50. Ivoke N, Ogbonna PC, Ekeh FN, Ezenwaji NE, Atama CI, Ejere VC, Onoja US, Eyo JE. Effects of grapefruit (Citrus paradisi MACF) (Rutaceae) peel oil against developmental stages of Aedes aegypti (Diptera: Culicidae), Southeast Asian. J Trop Med Public Health. 2013;44:970–8.
51. Swingle WT. The botany of citrus and its wild relations. Citrus Ind. 1967;1:190–422.
52. Ortuño A, Báidez A, Gómez P, Arcas M, Porras I, García-Lidón A, Del Río J. Citrus paradisi and Citrus sinensis flavonoids: their influence in the defence mechanism against Penicillium digitatum. Food Chem. 2006;98(2):351–8.
53. Attaway JA, Pieringer AP, Barabas LJ. The origin of citrus flavor components—III A study of the percentage variations in peel and leaf oil terpenes during one season. Phytochemistry. 1967;6(1):25–32.
54. Okunowo WO, Oyedeji O, Afolabi LO, Matanmi E, Essential oil of grape fruit (Citrus paradisi) peels and its antimicrobial activities, 2013.
55. Hamdan DI, Abdulla RH, Mohamed ME, El-Shazly AM. Chemical composition and biological activity of essential oils of Cleopatra mandarin (Citrus reshni) cultivated in Egypt. J Pharmacogn Phytother. 2013;5(5):83–90.
56. Lota ML, de Rocca Serra D, Tomi F, Casanova J. Chemical variability of peel and leaf essential oils of 15 species of mandarins. Biochem Syst Ecol. 2001;29(1):77–104.
57. Dalia IH, Rehab HA, Maged EM, Assem ME-S. Chemical composition and biological activity of essential oils of Cleopatra mandarin (Citrus reshni) cultivated in Egypt. J Pharmacogn Phytother. 2013;5(5):83–90.
58. Nagy MM, Al-Mahdy DA, Abd El Aziz OM, Kandil AM, Tantawy MA, El Alfy TS. Chemical composition and antiviral activity of essential oils from Citrus reshni Hort ex Tanaka (Cleopatra mandarin) cultivated in Egypt. J Essent Oil Bear Plants. 2018;21(1):264–72.
59. Song H, Sawamura M, Ito T, Ukeda H. Chemical compositions of the volatile part of yuzu (Citrus junos Tanaka) peel cold-pressed oils from Japan and Korea. Flavour Fragr J. 1999;14(6):383–9.
60. Kim T-H, Kim H-M, Park SW, Jung Y-S. Inhibitory effects of yuzu and its components on human platelet aggregation. Biomol Ther. 2015;23(2):149.
61. Lee T, Chang YH. Structural, physicochemical, and in-vitro release properties of hydrogel beads produced by oligochitosan and de-esterified pectin from yuzu (Citrus junos) peel as a quercetin delivery system for colon target. Food Hydrocoll. 2020;108: 106086.
62. Sawamura M. Aroma and functional properties of Japanese yuzu (Citrus junos Tanaka) essential oil. Aroma Res. 2000;1(1):14–9.
63. Lee BB, Kim YM, Pyeon SM, Jeong HJ, Cho YS, Nam SH. Physiochemical properties and neuroprotective function of Korean major yuzu varieties. Food Sci Technol. 2022;19(42):e69222.

64. Wang Y-W, Zeng W-C, Xu P-Y, Lan Y-J, Zhu R-X, Zhong K, Huang Y-N, Gao H. Chemical composition and antimicrobial activity of the essential oil of kumquat (Fortunella crassifolia Swingle) peel. Int J Mol Sci. 2012;13(3):3382–93.
65. Koyasako A, Bernhard R. Volatile constituents of the essential oil of kumquat. J Food Sci. 1983;48(6):1807–12.
66. González-Mas MC, Rambla JL, López-Gresa MP, Blázquez MA, Granell A. Volatile compounds in citrus essential oils: A comprehensive review. Front Plant Sci. 2019;10:12.
67. Ngo T, Tran T, Nguyen V, Mai H. Optimization of green mandarin (Citrus reticulata) essential oil extraction using microwave-assisted hydrodistillation and chemical composition analysis, IOP Conference Series: Materials Science and Engineering. Springer, Cham: IOP Publishing; 2020.
68. Nogata Y, Ohta H, Sumida T, Sekiya K. Effect of extraction method on the concentrations of selected bioactive compounds in mandarin juice. J Agric Food Chem. 2003;51(25):7346–51.
69. Mandal S, Mandal M. Tangerine (Citrus reticulata L. var.) oils, Essential oils in food preservation, flavor and safety. Cham: Elsevier; 2016.
70. Agu K, Igweoha C, Umeh C. Antimicrobial activity of the ethanolic and petroleum ether extracts of tangerine seed on selected bacteria. Int J Agric Biosci. 2013;2(1):22–4.
71. Musara C, Aladejana EB, Mudyiwa SM. Review of the nutritional composition, medicinal, phytochemical and pharmacological properties of Citrus reticulata Blanco (Rutaceae). Research. 2020;9:1387.
72. Yi F, Jin R, Sun J, Ma B, Bao X. Evaluation of mechanical-pressed essential oil from Nanfeng mandarin (Citrus reticulata Blanco cv. Kinokuni) as a food preservative based on antimicrobial and antioxidant activities. Lwt. 2018;95:346–53.
73. Belletti N, Ndagijimana M, Sisto C, Guerzoni ME, Lanciotti R, Gardini F. Evaluation of the antimicrobial activity of citrus essences on Saccharomyces cerevisiae. J Agric Food Chem. 2004;52(23):6932–8.
74. Das DR, Sachan AK, Shuaib M, Imtiyaz M. Chemical charecterization of volatile oil components of Citrus reticulata by GC-MS analysis. Nitric Oxide. 2014;1(1):243.
75. Bousbia N, Vian MA, Ferhat MA, Petitcolas E, Meklati BY, Chemat F. Comparison of two isolation methods for essential oil from rosemary leaves: hydrodistillation and microwave hydrodiffusion and gravity. Food Chem. 2009;114(1):355–62.
76. Shirsath S, Sonawane S, Gogate P. Intensification of extraction of natural products using ultrasonic irradiations—a review of current status. Chem Eng Process. 2012;53:10–23.
77. Sharma K, Mahato N, Cho MH, Lee YR. Converting citrus wastes into value-added products: economic and environmently friendly approaches. Nutrition. 2017;34:29–46.
78. Negro V, Mancini G, Ruggeri B, Fino D. Citrus waste as feedstock for bio-based products recovery: review on limonene case study and energy valorization. Biores Technol. 2016;214:806–15.
79. Panda D, Manickam S. Cavitation technology—The future of greener extraction method: a review on the extraction of natural products and process intensification mechanism and perspectives. Appl Sci. 2019;9(4):766.
80. Mahato N, Sinha M, Sharma K, Koteswararao R, Cho MH. Modern extraction and purification techniques for obtaining high purity food-grade bioactive compounds and value-added co-products from citrus wastes. Foods. 2019;8(11):523.
81. Radwan MN, Morad M, Ali M, Wasfy KI. A solar steam distillation system for extracting lavender volatile oil. Energy Rep. 2020;6:3080–7.
82. Saldaña-Mendoza SA, Chávez-González ML, Ramírez-Guzmán N, Pacios-Michelena S, Aguilar CN. Technological trends in the extraction of essential oils. Environ Quality Manag. 2022;32(1):441–50.
83. Mercy N, Nithyalakshmi B, Aadhithiya L. Extraction of orange oil by improved steam distillation and its characterization Studies. Int J Eng Technol Manag Appl Sci. 2015;3(2):2349–4476.
84. Li Y, Fabiano-Tixier AS, Chemat F. Essential oils as reagents in green chemistry. Cham: Springer; 2014.
85. Kademi HI, Garba U. Citrus peel essential oils: a review on composition and antimicrobial activities. Int J Food Saf Nutr Public Health Technol. 2017;9(5):38–44.
86. Shakir IK, Salih SJ. Extraction of essential oils from citrus by-products using microwave steam distillation. Iraq J Chem Petrol Eng. 2015;16(3):11–22.
87. Tirado CB, Stashenko EE, Combariza MY, Martinez JR. Comparative study of Colombian citrus oils by high-resolution gas chromatography and gas chromatography-mass spectrometry. J Chromatogr A. 1995;697(1–2):501–13.
88. Gamarra F, Sakanaka L, Tambourgi E, Cabral F. Influence on the quality of essential lemon (Citrus aurantifolia) oil by distillation process. Braz J Chem Eng. 2006;23:147–51.
89. Aibinu I, Adenipekun T, Adelowotan T, Ogunsanya T, Odugbemi T. Evaluation of the antimicrobial properties of different parts of Citrus aurantifolia (lime fruit) as used locally. Afr J Tradit Complement Altern Med. 2007;4(2):185.
90. Adusei-Mensah F, Inkum E, Mawuli Agbale C, Eric A. Comparative evaluation of the insecticidal and insect repellent properties of the volatile oils of Citrus aurantifolia (Lime) Citrus sinensis (Sweet orange) and Citrus limon (Lemon) on Camponotus nearcticus (Carpenter ants). Int J Novel Res Interdiscip Stud. 2014;1(2):19–25.
91. Sikdar D, Menon R, Duseja K, Kumar P, Swami P. Extraction of citrus oil from orange (Citrus sinensis) peels by steam distillation and its characterizations. Int J Tech Res Appl. 2016;4(3):341–6.
92. Giwa SO, Muhammad M, Giwa A. Utilizing orange peels for essential oil production. J Eng App Sci. 2018;13:17–27.
93. Yahaya MF, Kubmarawa D, Yelwa JM, Runde M. Antioxidant and antimicrobial activity of essential oils extracted from aromatic plants. World Sci News. 2018;111:13–25.
94. Kusuma H, Putra A, Mahfud M. Comparison of two isolation methods for essential oils from orange peel (Citrus auranticum L.) as a growth promoter for fish: Microwave steam distillation and conventional steam distillation. J Aquac Res Dev. 2016;7:409.
95. Taghadomi-Saberi S, Mas Garcia S, Allah Masoumi A, Sadeghi M, Marco S. Classification of bitter orange essential oils according to fruit ripening stage by untargeted chemical profiling and machine learning. Sensors. 2018;18(6):1922.
96. Lin M, Zhou A, Yang H, Xie W, Li X, Liu Z, Chen X. Research on the extraction of bergamot essential oil by steam distillation and component analysis. J Food Saf Qual. 2015;6(2):619–25.
97. Colecio-Juárez MC, Rubio-Núñez RE, Botello-Álvarez JE, Martínez-González GM, Navarrete-Bolaños JL, Jiménez-Islas H. Characterization of volatile compounds in the essential oil of sweet lime (Citrus limetta Risso). Chilean J Agric Res. 2012;72(2):275.

98. Thapa S, Poudel K, Limbu SK, Dahal G, Pokhrel S. Phytochemical screening. GC Anal Antibact Activity Citrus limon Peel Extract Essent Oil J Nepal Chem Soc. 2022;43(1):69–75.
99. Etta-francis IB, Akpa J, Ehirim E. Comparative study on the analysis and utilization of citrus peels essential oil and pectin. Icon Res Eng. 2022;5:402–11.
100. Ammad F, Moumen O, Gasem A, Othmane S, Hisashi KN, Zebib B, Merah O. The potency of lemon (Citrus limon L.) essential oil to control some fungal diseases of grapevine wood. CR Biol. 2018;341(2):97–101.
101. Li C, Cai Q, Wu X, Tan Z, Huang S, Wei C, Zhang W, Chen Z, Zhang L, Xiang H. Variation in compositions and biological activities of essential oils from four citrus species: citrus Limon, citrus Sinensis, citrus Paradisi, and citrus Reticulata. Chem Biodivers. 2022;19(4): e202100910.
102. Yahaya MF, Yelwa JM, Abdullahi S, Umar JB, Abubakar AM, Babakura M. Chemical compositions, FTIR and larvicidal activity of essential oils extracted from aromatic plants. Eur Sci J. 2019;15(24):111–31.
103. Moravvej G, Hassanzadeh-Khayyat M, Abbar S. Vapor activity of essential oils extracted from fruit peels of two Citrus species against adults of Callosobruchus maculatus (Fabricius, 1775)(Coleoptera: Bruchidae). Turk J Entomol. 2010;34(3):279–88.
104. Chen M-H, Yang K-M, Huang T-C, Wu M-L. Traditional small-size citrus from Taiwan: essential oils, bioactive compounds and antioxidant capacity. Medicines. 2017;4(2):28.
105. Peng LW, Sheu MJ, Lin LY, Wu CT, Chiang HM, Lin WH, Lee MC, Chen HC. Effect of heat treatments on the essential oils of kumquat (Fortunella margarita Swingle). Food Chem. 2013;136(2):532–7.
106. Ngo T, Tran T, Dao T, Tran T, Ngo H, Huynh X, Tran T, Mai H. Yield and composition analysis of Vietnamese lemon (Citrus aurantifolia) essential oils obtained from hydrodistillation and microwave-assisted hydrodistillation, IOP Conference Series: Materials Science and Engineering. Sorinfer, Cham: IOP Publishing; 2020.
107. Golmohammadi M, Borghei A, Zenouzi A, Ashrafi N, Taherzadeh MJ. Optimization of essential oil extraction from orange peels using steam explosion. Heliyon. 2018;4(11): e00893.
108. Akdağ A, Öztürk E. Distillation methods of essential oils. Selçuk Üniv Fen Fakültesi Fen Dergisi. 2018;45(1):22–31.
109. Suetsugu T, Tanaka M, Iwai H, Matsubara T, Kawamoto Y, Saito C, Sasaki Y, Hoshino M, Quitain AT, Sasaki M. Supercritical CO 2 extraction of essential oil from Kabosu (Citrus sphaerocarpa Tanaka) peel. Flavour. 2013;2(1):18.
110. Kowalski R, Gagoś M, Kowalska G, Pankiewicz U, Sujka M, Mazurek A, Nawrocka A. Effects of ultrasound technique on the composition of different essential oils. J Anal Methods Chem. 2019;2019(1):6782495.
111. Moradi S, Fazlali A, Hamedi H. Microwave-assisted hydro-distillation of essential oil from rosemary: comparison with traditional distillation. Avic J Med Biotechnol. 2018;10(1):22.
112. Seidi Damyeh M, Niakousari M, Golmakani MT, Saharkhiz MJ. Microwave and ohmic heating impact on the in situ hydrodistillation and selective extraction of Satureja macrosiphonia essential oil. J Food Process Preserv. 2016;40(4):647–56.
113. Meyer-Warnod B. Natural essential oils: extraction processes and application to some major oils. Perfum Flavorist. 1984;9(2):93–104.
114. Roohinejad S, Koubaa M, Barba FJ, Leong SY, Khelfa A, Greiner R, Chemat F. Extraction methods of essential oils from herbs and spices. Essent Oils Food Process Chem Saf Appl. 2017;22:21–55.
115. Périno-Issartier S, Ginies C, Cravotto G, Chemat F. A comparison of essential oils obtained from lavandin via different extraction processes: Ultrasound, microwave, turbohydrodistillation, steam and hydrodistillation. J Chromatogr A. 2013;1305:41–7.
116. Gavahian M, Farahnaky A, Javidnia K, Majzoobi M. Comparison of ohmic-assisted hydrodistillation with traditional hydrodistillation for the extraction of essential oils from Thymus vulgaris L. Innov Food Sci Emerg Technol. 2012;14:85–91.
117. Filly A, Fabiano-Tixier AS, Louis C, Fernandez X, Chemat F. Water as a green solvent combined with different techniques for extraction of essential oil from lavender flowers. C R Chim. 2016;19(6):707–17.
118. Kamal G, Anwar F, Hussain A, Sarri N, Ashraf M. Yield and chemical composition of Citrus essential oils as affected by drying pretreatment of peels. Int Food Res J. 2011;18(4):1275.
119. Ferreira LE, Benincasa BI, Fachin AL, Contini SHT, França SC, Chagas ACS, Beleboni RO. Essential oils of citrus aurantifolia. Anthemis Nobile Lavandula Officinalis vitro Anthelmintic Activities Against Haemonchus Contortus Parasites Vectors. 2018;11(1):1–9.
120. Golmakani MT, Moayyedi M. Comparison of heat and mass transfer of different microwave-assisted extraction methods of essential oil from Citrus limon (Lisbon variety) peel. Food Sci Nutr. 2015;3(6):506–18.
121. Tavallali H, Bahmanzadegan A, Rowshan V, Tavallali V. Essential oil composition, antioxidant activity, phenolic compounds, total phenolic and flavonoid contents from pomace of Citrus aurantifolia. J Med Plants Prod. 2021;1(10):103–16.
122. Aboudaou M, Ferhat MA, Hazzit M, Ariño A, Djenane D. Solvent free-microwave green extraction of essential oil from orange peel (Citrus sinensis L.): effects on shelf life of flavored liquid whole eggs during storage under commercial retail conditions. J Food Measur Charact. 2019;13(4):3162–72.
123. Ngan T, Nguyen O, Muoi N, Truc T, My V. Chemical composition and antibacterial activity of orange (Citrus sinensis) essential oils obtained by hydrodistillation and solvent free microwave extraction, IOP Conference Series: Materials Science and Engineering. Springer, Cham: IOP Publishing; 2020.
124. Zewde DK, Jembere B. Evaluation of orange peel citrus sinensis (L) as a source of repellent, toxicant and protectant against Zabrotes subfasciatus (Coleoptera: bruchidae). Momona Ethiop J Sci. 2010;2(1):1.
125. Nazlina Z, Chan M, Angelynn J, Choo CM. Kinetic study of hydrodistillation of citrus sinensis and quality of the oil. Int J Eng Technol. 2017;17(01):42–6.
126. Tabti L, Dib MEA, Gaouar N, Samira B, Tabti B. Antioxidant and antifungal activity of extracts of the aerial parts of Thymus capitatus (L.) Hoffmanns against four phytopathogenic fungi of Citrus sinensis. Jundishapur J Nat Pharm Prod. 2014;9(1):49–54.
127. Ferhat MA, Meklati BY, Smadja J, Chemat F. An improved microwave clevenger apparatus for distillation of essential oils from orange peel. J Chromatogr A. 2006;1112(1–2):121–6.
128. Djenane D. Chemical profile, antibacterial and antioxidant activity of Algerian citrus essential oils and their application in Sardina pilchardus. Foods. 2015;4(2):208–28.
129. Sarrou E, Chatzopoulou P, Dimassi-Theriou K, Therios I. Volatile constituents and antioxidant activity of peel, flowers and leaf oils of Citrus aurantium L. growing in Greece. Molecules. 2013;18(9):10639–47.

130. Nabiha B, Abdelfatteh E, Faten K, Hervé C, Moncef C. Chemical composition of bergamot (Citrus bergamia Risso) essential oil obtained by hydrodistillation. J Chem Chem Eng. 2010;4(29):60–2.
131. Kaskoos RA. Essential oil analysis by GC-MS and analgesic activity of Lippia citriodora and citrus limon. J Essent Oil Bear Plants. 2019;22(1):273–81.
132. Moosavy M, Hassanzadeh P, Mohammadzadeh E, Mahmoudi R, Khatibi S, Mardani K. Antioxidant and antimicrobial activities of essential oil of Lemon (Citrus limon) peel in vitro and in a food model. J Food Quality Hazards Control. 2017;4(2):42–8.
133. Safaeian Laein S, Salari A, Shahsavani D, Haghishani H. Evaluation of antibacterial and antioxidant activities of essential oil of lime (Citrus aurantifolia) pomace powder. Iran J Chem Chem Eng IJCCE. 2021;40(3):832–40.
134. Manaila E, Berechet MD, Stelescu MD, Craciun G, Mihaiescu DE, Purcareanu B, Calinescu I, Fudulu A, Radu M. Comparation between chemical compositions of some essential oils obtained by hydrodistillation from citrus peels. Rev Chim. 2016;67:106.
135. Jomaa S, Rahmo A, Alnori AS, Chatty ME, The cytotoxic effect of essential oil of Syrian Citrus limon peel on human colorectal carcinoma cell line 2012:Lim1863.
136. Loizzo MR, Tundis R, Bonesi M, Sanzo GD, Verardi A, Lopresto CG, Pugliese A, Menichini F, Balducchi R, Calabrò V. Chemical profile and antioxidant properties of extracts and essential oils from Citrus× limon (L.) burm Cv. Femminello Comune Chem Biodivers. 2016;13(5):571–81.
137. Fancello F, Petretto GL, Zara S, Sanna ML, Addis R, Maldini M, Foddai M, Rourke JP, Chessa M, Pintore G. Chemical characterization, antioxidant capacity and antimicrobial activity against food related microorganisms of citrus limon var. pompia leaf essential oil, LWT-Food. Sci Technol. 2016;69:579–85.
138. Al-Jabri NN, Hossain MA. Comparative chemical composition and antimicrobial activity study of essential oils from two imported lemon fruits samples against pathogenic bacteria. Beni-Suef Univ J Basic Appl Sci. 2014;3(4):247–53.
139. Ou MC, Liu YH, Sun YW, Chan CF. The composition, antioxidant and antibacterial activities of cold-pressed and distilled essential oils of citrus paradisi and citrus grandis (L) Osbeck. Evid Based Complement Altern Med. 2015;2015(1):804091.
140. Oshaghi M, Ghalandari R, Vatandoost H, Shayeghi M, Kamali-Nejad M, Tourabi-Khaledi H, Abolhassani M, Hashemzadeh M. Repellent effect of extracts and essential oils of citrus limon (Rutaceae) and melissa officinalis (Labiatae) against main malaria vector, anopheles stephensi (diptera: culicidae). Iran J Public Health. 2003;32(4):47–52.
141. Bouzenna H, Dhibi S, Samout N, Rjeibi I, Talarmin H, Elfeki A, Hfaiedh N. The protective effect of citrus limon essential oil on hepatotoxicity and nephrotoxicity induced by aspirin in rats. Biomed Pharmacother. 2016;83:1327–34.
142. Denkova-Kostova R, Teneva D, Tomova T, Goranov B, Denkova Z, Shopska V, Slavchev A, Hristova-Ivanova Y. Chemical composition, antioxidant and antimicrobial activity of essential oils from tangerine (citrus reticulata L.), grapefruit (citrus paradisi L.), lemon (citrus lemon L.) and cinnamon (cinnamomum zeylanicum Blume). Zeitschrift für Naturforschung C. 2021;76(5–6):175–85.
143. Fontenele MA, Gomes PR, Oliveira MB, de Sousa DA, da Silva JC, Fernandes RP, Louzeiro HC, de Oliveira RW, de Paula MD, Mouchrek Filho VE. Larvicidal activity, molluscicide and toxicity of the essential oil of Citrus limon peels against, respectively, Aedes aegypti, Biomphalaria glabrata and Artemia salina. Eclét Química. 2019;44(4):85–95.
144. Mohamed RA, Yousef YM, El-Tras WF, Khalafallaa MM. Dietary essential oil extract from sweet orange (Citrus sinensis) and bitter lemon (Citrus limon) peels improved Nile tilapia performance and health status. Aquac Res. 2021;52(4):1463–79.
145. Lopresto CG, Meluso A, Di Sanzo G, Chakraborty S, Calabrò V. Process-intensified waste valorization and environmentally friendly d-limonene extraction. Euro-Mediterr J Environ Integr. 2019;4(1):1–12.
146. Javed S, Javaid A, Nawaz S, Saeed M, Mahmood Z, Siddiqui S, Ahmad R. Phytochemistry, GC-MS analysis, antioxidant and antimicrobial potential of essential oil from five citrus species. J Agric Sci. 2014;6(3):201.
147. Kaanin-Boudraa G, Brahmi F, Wrona M, Nerín C, Hadjal S, Madani K, Boulekbache-Makhlouf L. Citrus× paradisi essential oil as a promising agent for margarine storage stability: Composition and antioxidant capacity. J Food Process Preserv. 2021;45(5): e15374.
148. Sharma, K. Mahato, N. Cho, M.H. Lee, Y.R. Converting citrus wastes into value-added products: Economic and environmently friendly approaches, Nutrition 2017; 34: 29–46.
149. Job JT, Visakh NU, Pathrose B, Alfarhan A, Rajagopal R, Thayyullathil J, Thejass P, Ramesh V, Narayanankutty A. Chemical composition and biological activities of the essential oil from citrus reticulata blanco peels collected from agrowastes. Chem Biodivers. 2024;21(3):e202301223.
150. Amorim JL, Simas DLR, Pinheiro MMG, Moreno DSA, Alviano CS, da Silva AJR, Fernandes PD. Anti-inflammatory properties and chemical characterization of the essential oils of four citrus species. PLoS ONE. 2016;11(4):1.
151. Tunç MT, Odabaş Hİ. Single-step recovery of pectin and essential oil from lemon waste by ohmic heating assisted extraction/hydrodistillation: a multi-response optimization study. Innov Food Sci Emerg Technol. 2021;74: 102850.
152. Brahmi F, Mokhtari O, Legssyer B, Hamdani I, Asehraou A, Hasnaoui I, Rokni Y, Diass K, Oualdi I, Tahani A. Chemical and biological characterization of essential oils extracted from citrus fruits peels. Mater Today Proceed. 2021;45:7794–9.
153. Fidalgo A, Ciriminna R, Carnaroglio D, Tamburino A, Cravotto G, Grillo G, Ilharco LM, Pagliaro M. Eco-friendly extraction of pectin and essential oils from orange and lemon peels. ACS Sustain Chem Eng. 2016;4(4):2243–51.
154. Sutour S, Luro F, Casanova J, Tomi F. Integrated analysis by GC (RI), GC-MS and 13C NMR of Fortunella japonica leaf volatiles obtained by hydrodistillation, microwave-assisted hydrodistillation and hydrolate extraction. Nat Product Commun. 2017;12(3):1.
155. Chávez-González ML, López-López LI, Rodríguez-Herrera R, Contreras-Esquivel JC, Aguilar CN. Enzyme-assisted extraction of citrus essential oil. Chem Pap. 2016;70(4):412–7.
156. Taktak O, Ben Youssef S, Abert Vian M, Chemat F, Allouche N. Physical and chemical influences of different extraction techniques for essential oil recovery from Citrus sinensis peels. J Essent Oil Bear Plants. 2021;24(2):290–303.
157. El Houda AKN, Ali B, Ahmed A, Salah O, Yazid F-C. Chemical composition, antimicrobial and insecticidal activities of citrus paradisi peel essential oil from Algeria. J Microbiol Biotechnol Food Sci. 2020;9(6):1093–8.
158. Pragna CH, Ranjitha Gracy TK, Mahendran R, Anandharamakrishnan C. Effects of microwave and cold plasma assisted Hydrodistillation on lemon Peel oil extraction. Int J Food Eng. 2019;15(10):20190093.
159. Yu P, Yang Y, Sun J, Jia X, Zheng C, Zhou Q, Huang F. Identification of volatile sulfur-containing compounds and the precursor of dimethyl sulfide in cold-pressed rapeseed oil by GC–SCD and UPLC–MS/MS. Food Chem. 2022;367: 130741.
160. Çakaloğlu B, Özyurt VH, Ötleş S. Cold press in oil extraction A review. Ukrainian Food J. 2018;7(4):640–54.

161. Bousbia N, Vian MA, Ferhat MA, Meklati BY, Chemat F. A new process for extraction of essential oil from citrus peels: microwave hydrodiffusion and gravity. J Food Eng. 2009;90(3):409–13.
162. Vasek O, Cáceres L, Chamorro E, Velasco G. Antibacterial activity of citrus paradisi essential oil. J Nat Prod. 2015;8:16–26.
163. Azar AP, Nekoei M, Larijani K, Bahraminasab S. Chemical composition of the essential oils of Citrus sinensis cv. valencia and a quantitative structure-retention relationship study for the prediction of retention indices by multiple linear regression. J Serbian Chem Soc. 2011;76(12):1627–37.
164. Quintero A, Gonzalez C, Sanchez F, Usubillaga A, Rojas L. Constituents and biological activity of citrus aurantium amara L. essential oil. Int Conf Med Aromat Plants Part II. 2001;597:115–7.
165. Kirbaşlar FG, Tavman A, Dülger B, Türker G. Antimicrobial activity of Turkish citrus peel oils. Pak J Bot. 2009;41(6):3207–12.
166. Nekoei M, Mohammadhosseini M. Application of HS-SPME, SDME and cold-press coupled to GC/MS to analysis the essential oils of Citrus sinensis CV. Thomson Navel QSRR Study Prediction Retent Indices Stepwise Genet Algorithm Mult Linear Regression Approaches Anal Chem Lett. 2014;4(2):93–103.
167. Guneser BA, Yilmaz E. Bioactives, aromatics and sensory properties of cold-pressed and hexane-extracted lemon (Citrus limon L.) seed oils. J Am Oil Chem Soc. 2017;94(5):723–31.
168. Bonaccorsi I, Sciarrone D, Cotroneo A, Mondello L, Dugo P, Dugo G. Enantiomeric distribution of key volatile components in citrus essential oils, revista brasileira de. Farmacognosia. 2011;21:841–9.
169. Yang F, Zhang H, Tian G, Ren W, Li J, Xiao H, Zheng J. Effects of molecular distillation on the chemical components. Clean Antibact Abilities Four Differ Citrus Oils Front Nutr. 2021;8: 731724.
170. Himed L, Merniz S, Monteagudo-Olivan R, Barkat M, Coronas J. Antioxidant activity of the essential oil of citrus limon before and after its encapsulation in amorphous SiO2. Sci Afr. 2019;6: e00181.
171. Schipilliti L, Dugo P, Bonaccorsi I, Mondello L. Authenticity control on lemon essential oils employing gas chromatography–combustion-isotope ratio mass spectrometry (GC–C-IRMS). Food Chem. 2012;131(4):1523–30.
172. Deng W, Liu K, Cao S, Sun J, Zhong B, Chun J. Chemical composition, antimicrobial, antioxidant, and antiproliferative properties of grapefruit essential oil prepared by molecular distillation. Molecules. 2020;25(1):217.
173. El-Toumy SA, Hussein AA. Cold pressed yuzu (Citrus junos Sieb. ex Tanaka) oil. Elsevier, Cham: Cold Pressed Oils; 2020.
174. Lan-Phi NT, Shimamura T, Ukeda H, Sawamura M. Chemical and aroma profiles of yuzu (citrus junos) peel oils of different cultivars. Food Chem. 2009;115(3):1042–7.
175. Njoroge SM, Sawamura M. Preparation of citrus essential oils: effects of silica gel treatment on volatile composition of yuzu (citrus junos) cold-pressed peel oil. J Essent Oil Bear Plants. 2004;7(1):1–8.
176. Bento R, Pagán E, Berdejo D, de Carvalho RJ, García-Embid S, Maggi F, Magnani M, de Souza EL, García-Gonzalo D, Pagán R. Chitosan nanoemulsions of cold-pressed orange essential oil to preserve fruit juices. Int J Food Microbiol. 2020;331: 108786.
177. Freitas LC, Moraes VS, da Silva SB, de Carvalho Junior RN. Acquisition of essential oils through traditional techniques. Essent Oils Extr Methods Appl. 2023;14:859–69.
178. Ramadan MF. Introduction to cold pressed oils: Green technology, bioactive compounds, functionality, and applications. Cold pressed oils: Elsevier; 2020. p. 1–5.
179. Fokou JBH, Dongmo PMJ, Boyom FF, Essential oil's chemical composition and pharmacological properties, Essential oils-oils of nature, IntechOpen 2020.
180. Jayaprakasha GK, Negi PS, Sikder S, Mohanrao LJ, Sakariah KK. Antibacterial activity of Citrus reticulata peel extracts. Zeitschrift für Naturforschung C. 2000;55(11–12):1030–4.
181. Javed S, Javaid A, Mahmood Z, Javaid A, Nasim F. Biocidal activity of citrus peel essential oils against some food spoilage bacteria. J Med Plants Res. 2011;5(16):3697–701.
182. Sumonrat C, Suphitchaya C, Tipparat H. Antimicrobial activities of essential oils and crude extracts from tropical citrus spp. against food-related microorganisms. Songklanakarin J Sci Technol. 2008;30(1):125–31.
183. Hasibuan R, Gultom E. The effect of method, type of solvent and extraction time towards the yield of oil on essential oil extraction from lime peel (Citrus aurantifolia), IOP Conference Series: Materials Science and Engineering. Springer, Cham: IOP Publishing; 2021.
184. Zhang H, Lou Z, Chen X, Cui Y, Wang H, Kou X, Ma C. Effect of simultaneous ultrasonic and microwave assisted hydrodistillation on the yield, composition, antibacterial and antibiofilm activity of essential oils from Citrus medica L. var sarcodactylis. J Food Eng. 2019;244:126–35.
185. Sheikh M, Mehnaz S, Sadiq MB. Prevalence of fungi in fresh tomatoes and their control by chitosan and sweet orange (Citrus sinensis) peel essential oil coating. J Sci Food Agric. 2021;101(15):6248–57.
186. Adebisi O. Comparative study of essential oil composition of fresh and dry peel and seed of Citrus sinensis (L) Osbeck var shamuti and Citrus Paradise Macfadyen var Marsh. IFE J Sci. 2014;16(2):211–7.
187. Fakayode OA, Abobi KE. Optimization of oil and pectin extraction from orange (Citrus sinensis) peels: a response surface approach. J Anal Sci Technol. 2018;9(1):1–16.
188. Di Rauso Simeone G, Di Matteo A, Rao MA, Di Vaio C. Variations of peel essential oils during fruit ripening in four lemon (Citrus limon (L.) Burm. F.) cultivars. J Sci Food Agric. 2020;100(1):193–200.
189. Lopresto CG, Petrillo F, Casazza AA, Aliakbarian B, Perego P, Calabrò V. A non-conventional method to extract D-limonene from waste lemon peels and comparison with traditional Soxhlet extraction. Sep Purif Technol. 2014;137:13–20.
190. Zang L, Shimada Y, Kawajiri J, Tanaka T, Nishimura N. Effects of Yuzu (Citrus junos Siebold ex Tanaka) peel on the diet-induced obesity in a zebrafish model. J Funct Foods. 2014;1(10):499–510.
191. Sicari V, Poiana M. Comparison of the volatile component of the essential oil of kumquat (Fortunella margarita swingle) extracted by supercritical carbon dioxide, hydrodistillation and conventional solvent extraction. J Essent Oil Bear Plants. 2017;20(1):87–94.
192. Chisholm MG, Wilson MA, Gaskey GM. Characterization of aroma volatiles in key lime essential oils (Citrus aurantifolia Swingle). Flavour Fragr J. 2003;18(2):106–15.
193. Zhuang X, Zhang Z, Wang Y, Li Y. The effect of alternative solvents to n-hexane on the green extraction of Litsea cubeba kernel oils as new oil sources. Ind Crops Prod. 2018;126:340–6.

194. Sahraoui N, Vian MA, El Maataoui M, Boutekedjiret C, Chemat F. Valorization of citrus by-products using Microwave Steam Distillation (MSD). Innov Food Sci Emerg Technol. 2011;12(2):163–70.
195. Golmakani M-T, Moayyedi M. Comparison of microwave-assisted hydrodistillation and solvent-less microwave extraction of essential oil from dry and fresh Citruslimon (Eureka variety) peel. J Essent Oil Res. 2016;28(4):272–82.
196. Bustamante J, van Stempvoort S, García-Gallarreta M, Houghton JA, Briers HK, Budarin VL, Matharu AS, Clark JH. Microwave assisted hydro-distillation of essential oils from wet citrus peel waste. J Clean Prod. 2016;137:598–605.
197. Toan T, Truc T, Le X, Quyen N, Tran T. Study on extraction process and analysis of components in essential oils of Vietnamese orange peel (Citrus sinensis) by microwave assisted hydrodistillation extraction, IOP Conference Series: Materials Science and Engineering. Springer, Cham: IOP Publishing; 2020.
198. Yu F, Wan N, Zheng Q, Li Y, Yang M, Wu Z. Effects of ultrasound and microwave pretreatments on hydrodistillation extraction of essential oils from Kumquat peel. Food Sci Nutr. 2021;9(5):2372–80.
199. Franco-Vega A, López-Malo A, Palou E, Ramírez-Corona N. Effect of imidazolium ionic liquids as microwave absorption media for the intensification of microwave-assisted extraction of Citrus sinensis peel essential oils. Chem Eng Process Process Intensif. 2021;160: 108277.
200. Ong HF, Extraction of essential oil from orange peels, UMP, 2012.
201. Ciriminna R, Fidalgo A, Delisi R, Carnaroglio D, Grillo G, Cravotto G, Tamburino A, Ilharco LM, Pagliaro M. High-quality essential oils extracted by an eco-friendly process from different citrus fruits and fruit regions. ACS Sustain Chem Eng. 2017;5(6):5578–87.
202. Uysal B, Sozmen F, Aktas O, Oksal BS, Kose EO. Essential oil composition and antibacterial activity of the grapefruit (Citrus Paradisi. L) peel essential oils obtained by solvent-free microwave extraction: comparison with hydrodistillation. Int J Food Sci Technol. 2011;46(7):1455–61.
203. Xiao JB, Chen JW, Xu M. Supercritical fluid CO2 extraction of essential oil from Marchantia convoluta: global yields and extract chemical composition. Electron J Biotechnol. 2007;10(1):141–8.
204. Capuzzo A, Maffei ME, Occhipinti A. Supercritical fluid extraction of plant flavors and fragrances. Molecules. 2013;18(6):7194–238.
205. Hoshino M, Suetsugu T, Iwai H, Takamizu A, Tanaka M, Quitain A, Sasaki M, Goto M. Extraction of citrus flavonoids from peel of Citrus junos using supercritical carbon dioxide with polar solvent. Trans Mater Res Soc Jpn. 2014;39(3):309–11.
206. Jerković I, Družić J, Marijanović Z, Gugić M, Jokić S, Roje M. GC-FID/MS Profiling of supercritical CO2 extracts of peels from citrus aurantium, C. sinensis cv. Washington navel, C. sinensis cv. Tarocco and C. sinensis cv. Doppio Sanguigno from Dubrovnik Area (Croatia). Nat Product Commun. 2015;10(7):1.
207. Akolade JO, Nasir-Naeem KO, Swanepoel A, Yusuf AA, Balogun M, Labuschagne P. CO2-assisted production of polyethylene glycol/lauric acid microparticles for extended release of Citrus aurantifolia essential oil. J CO2 Util. 2020;38:375–84.
208. Sicari V, Poiana M. Recovery of bergamot seed oil by supercritical carbon dioxide extraction and comparison with traditional solvent extraction. J Food Process Eng. 2017;40(1): e12341.
209. Ueno H, Tanaka M, Machmudah S, Sasaki M, Goto M. Supercritical carbon dioxide extraction of valuable compounds from Citrus junos seed. Food Bioprocess Technol. 2008;1(4):357–63.
210. Hoshino M, Tanaka M, Sasaki M, Goto M, Extraction of essential oil from citrus junos peel using supercritical carbon dioxide, Proceedings of the 8th International Symposium Supercritical Fluids, CD-ROM, 2006.
211. Roy BC, Hoshino M, Ueno H, Sasaki M, Goto M. Supercritical carbon dioxide extraction of the volatiles from the peel of Japanese citrus fruits. J Essent Oil Res. 2007;19(1):78–84.
212. Marongiu B, Piras A, Porcedda S. Extraction of volatile fractions and carotenoids from orange and kumquat peel by supercritical carbon dioxide. J Essent Oil Bear Plants. 2003;6(2):86–96.
213. Rozzi N, Singh R. Supercritical fluids and the food industry. Compr Rev Food Sci Food Safety. 2002;1(1):33–44.
214. Liu X, Ou H, Xiang Z, Gregersen H. Ultrasound pretreatment combined with supercritical CO2 extraction of Iberis amara seed oil. J Appl Res Med Aromatic Plants. 2020;18: 100265.
215. Ma Y, Ye X, Hao Y, Xu G, Xu G, Liu D. Ultrasound-assisted extraction of hesperidin from Penggan (Citrus reticulata) peel. Ultrason Sonochem. 2008;15(3):227–32.
216. Khandare RD, Tomke PD, Rathod VK. Kinetic modeling and process intensification of ultrasound-assisted extraction of d-limonene using citrus industry waste. Chem Eng Process Process Intensif. 2021;159: 108181.
217. Assami K, Pingret D, Chemat S, Meklati BY, Chemat F. Ultrasound induced intensification and selective extraction of essential oil from Carum carvi L. seeds. Chem Eng Process Process Intensif. 2012;62:99–105.
218. Nora FM, Borges CD. Ultrasound pretreatment as an alternative to improve essential oils extraction. Ciência Rural. 2017;47(9):e20170173.
219. Xia T, Shi S, Wan X. Impact of ultrasonic-assisted extraction on the chemical and sensory quality of tea infusion. J Food Eng. 2006;74(4):557–60.
220. Alvarado-Morales G, Minjares-Fuentes R, Contreras-Esquivel JC, Montañez J, Meza-Velázquez JA, Femenia A. Application of thermosonication for Aloe vera (Aloe barbadensis Miller) juice processing: Impact on the functional properties and the main bioactive polysaccharides. Ultrason Sonochem. 2019;56:125–33.
221. Richa R, Kumar R, Shukla R, Khan K. Ultrasound assisted essential oil extraction technology: New boon in food industry. SKUAST J Res. 2020;22:78–85.
222. Chemat F, Rombaut N, Sicaire AG, Meullemiestre A, Fabiano-Tixier AS, Abert-Vian M. Ultrasound assisted extraction of food and natural products. Mechanisms, techniques, combinations, protocols and applications. Rev Ultrason Sonochem. 2017;1(34):540–60.
223. Meullemiestre A, Breil C, Abert-Vian M, Chemat F. Microwave, ultrasound, thermal treatments, and bead milling as intensification techniques for extraction of lipids from oleaginous Yarrowia lipolytica yeast for a biojetfuel application. Biores Technol. 2016;211:190–9.
224. Sandhu HK, Sinha P, Emanuel N, Kumar N, Sami R, Khojah E, Al-Mushhin AA. Effect of ultrasound-assisted pretreatment on extraction efficiency of essential oil and bioactive compounds from citrus waste by-products. Separations. 2021;8(12):244.
225. Liang Z, Shang XB, Su J, Li GY, Fu FH, Guo JJ, Shan Y. Alternative extraction methods of essential oil from the flowers of citrus aurantium L. var daidai tanaka: evaluation of oil quality and sedative-hypnotic activity. Nat Product Commun. 2021;16(3):1.

226. Yang L, Cao YL, Jiang JG, Lin QS, Chen J, Zhu L. Response surface optimization of ultrasound-assisted flavonoids extraction from the flower of Citrus aurantium L. var. amara Engl. J Sep Sci. 2010;33(9):1349–55.
227. Singanusong R, Nipornram S, Tochampa W, Rattanatraiwong P. Low power ultrasound-assisted extraction of phenolic compounds from mandarin (Citrus reticulata Blanco cv. Sainampueng) and lime (Citrus aurantifolia) peels and the antioxidant. Food Anal Methods. 2015;8(5):1112–23.
228. Jiang MH, Yang L, Zhu L, Piao JH, Jiang JG. Comparative GC/MS analysis of essential oils extracted by 3 methods from the bud of Citrus aurantium L. var. amara Engl. J Food Sci. 2011;76(9):C1219–25.
229. Wan N, Xie H, Yu F, Li Y, Zheng Q, Wu Z. Extraction of essential oils from Kumquat peel using ultrasound-assisted vacuum hydrodistillation. J Food Process Preserv. 2022;46(3): e16370.
230. Rahimi A, Hashemi P, Talei GR, Borzuei M, Ghiasvand AR. Comparative analyses of the volatile components of Citrus aurantium L. flowers using ultrasonic-assisted headspace SPME and hydrodistillation combined with GC-MS and evaluation of their antimicrobial activities. Anal Bioanal Chem Res. 2014;1(2):83–91.
231. Xing C, Qin C, Li X, Zhang F, Linhardt RJ, Sun P, Zhang A. Chemical composition and biological activities of essential oil isolated by HS-SPME and UAHD from fruits of bergamot. LWT. 2019;104:38–44.
232. Haggag EG, Wahab SA, Ei-Zalabany SM, Abou Moustafa EA, El-Kherasy EM. MABRYjit TO Volatile oils and pectins from citrus aurantifolia (Lime) and. Asian J Chem. 1998;10(4):828–33.
233. Lin L-Y, Chuang C-H, Chen H-C, Yang K-M. Lime (Citrus aurantifolia (Christm.) Swingle) essential oils: Volatile compounds, antioxidant capacity, and hypolipidemic effect. Foods. 2019;8(9):398.
234. Tran T, Ngo T, Tran T, Bach L, Tran T, Huynh X. Comparison of volatile compounds and antibacterial activity of Citrus aurantifolia, Citrus latifolia, and Citrus hystrix shell essential oils by pilot extraction, IOP Conference Series: Materials Science and Engineering. Springer, Cham: IOP Publishing; 2021.
235. Dongmo P, Tatsadjieu L, Sonwa ET, Kuate J, Zollo PA, Menut C. Essential oils of citrus aurantifolia from cameroon and their antifungal activity against phaeoramularia angolensis. Afr J Agric Res. 2009;4(4):354–8.
236. Ibrahim FA, Usman LA, Akolade JO, Idowu OA, Abdulazeez AT, Amuzat AO. Antidiabetic potentials of citrus aurantifolia leaf essential oil. Drug Res. 2019;69(04):201–6.
237. Ehsanfar P, Teimouri M, Pooladi M. Investigating characterizations and antifungal effects of solid lipid nanoparticles (SLNs) loaded with essential oil of Citrus Aurantifolia on isolated Malassezia strains. Arch Adv Biosci. 2020;11(3):43–55.
238. Fagodia SK, Singh HP, Batish DR, Kohli RK. Phytotoxicity and cytotoxicity of citrus aurantiifolia essential oil and its major constituents: limonene and citral. Ind Crops Prod. 2017;108:708–15.
239. Amorim JL, Simas DLR, Pinheiro MMG, Moreno DSA, Alviano CS, da Silva AJR, Dias Fernandes P. Anti-inflammatory properties and chemical characterization of the essential oils of four citrus species. PLoS ONE. 2016;11(4):e0153643.
240. Tundis R, Loizzo MR, Bonesi M, Menichini F, Mastellone V, Colica C, Menichini F. Comparative study on the antioxidant capacity and cholinesterase inhibitory activity of Citrus aurantifolia Swingle C. aurantium L., and C. bergamia Risso and Poit. peel essential oils. J Food Sci. 2012;77(1):H40–6.
241. Bozkurt T, Gülnaz O, Kaçar YA. Chemical composition of the essential oils from some citrus species and evaluation of the antimicrobial activity. J Environ Sci Toxicol Food Technol. 2017;11(10):29–33.
242. Galovičová L, Borotová P, Vukovic NL, Vukic M, Kunová S, Hanus P, Kowalczewski PŁ, Bakay L, Kačániová M. The potential use of Citrus aurantifolia L. essential oils for decay control, quality preservation of agricultural products, and anti-insect activity. Agronomy. 2022;12(3):735.
243. Dao T, Tran T, Nguyen P, Tran T, Ngo T, Nhan L, Anh T, Toan T, Quan P, Linh H. Optimization of microwave assisted hydrodistillation of essential oil from lemon (Citrus aurantifolia) leaves: Response surface methodology studies, IOP Conference Series: Materials Science and Engineering. Springer, Cham: IOP Publishing; 2020.
244. Saeidi M, Moharramipour S, Sefidkon F, Aghajanzadeh S. Insecticidal and repellent activities of citrus reticulata, citrus limon and citrus aurantium essential oils on callosobruchus maculatus. Integr Prot Stored Products IOBC/WPRS Bull. 2011;16(69):289–93.
245. Li P, Zeng S-L, Duan L, Ma X-D, Dou L-L, Wang L-J, Li P, Bi Z-M, Liu E-H. Comparison of Aurantii Fructus Immaturus and Aurantii Fructus based on multiple chromatographic analysis and chemometrics methods. J Chromatogr A. 2016;1469:96–107.
246. Bonaccorsi I, Sciarrone D, Schipilliti L, Fakhry H, Trozzi A, Dugo G. Composition of Egyptian nerolì oil. Nat Prod Commun. 2011;6(11):1009–14.
247. Mohagheghniapour A, Saharkhiz MJ, Golmakani MT, Niakousari M. Variations in chemical compositions of essential oil from sour orange (Citrus aurantium L.) blossoms by different isolation methods. Sustain Chem Pharm. 2018;10:118–24.
248. Hsouna AB, Hamdi N, Halima NB, Abdelkafi S. Characterization of essential oil from Citrus aurantium L. flowers: antimicrobial and antioxidant activities. J Oleo Sci. 2013;62(10):763–72.
249. Haj Ammar A, Bouajila J, Lebrihi A, Mathieu F, Romdhane M, Zagrouba F. Chemical composition and in vitro antimicrobial and antioxidant activities of Citrus aurantium L. flowers essential oil (Neroli oil). Pak J Biol Sci. 2012;15(21):1034–40.
250. Salma M, Abdellah F, El Houssine A, Kawtar B, Dalila B. Comparison of the chemical composition and the bioactivity of the essential oils of three medicinal and aromatic plants from Jacky Garden of Morocco. Int J Pharm Phytochem Res. 2016;8:537–45.
251. Duman E, Amir SoltanbeİGİ M. Chemical compositions of essential oil of some citrus spp (sour lemon kumquat Mandarin and Orange (peels. Zeitschrift für Arznei Gewürzpflanzen. 2016;21(4):153–9.
252. Ferhat M-A, Boukhatem MN, Hazzit M, Meklati BY, Chemat F. Cold pressing, hydrodistillation and microwave dry distillation of citrus essential oil from Algeria: a comparative study. Electron J Biol S. 2016;1:30–41.
253. Giovanelli S, Ciccarelli D, Giusti G, Mancianti F, Nardoni S, Pistelli L. Comparative assessment of volatiles in juices and essential oils from minor citrus fruits (Rutaceae). Flavour Fragr J. 2020;35(6):639–52.
254. Mandalari G, Bennett RN, Bisignano G, Saija A, Dugo G, Lo Curto RB, Faulds CB, Waldron KW. Characterization of flavonoids and pectins from bergamot (Citrus bergamia Risso) peel, a major byproduct of essential oil extraction. J Agric Food Chem. 2006;54(1):197–203.
255. Mandalari G, Bennett R, Bisignano G, Trombetta D, Saija A, Faulds C, Gasson M, Narbad A. Antimicrobial activity of flavonoids extracted from bergamot (Citrus bergamia Risso) peel, a byproduct of the essential oil industry. J Appl Microbiol. 2007;103(6):2056–64.

256. Donato P, Bonaccorsi I, Russo M, Dugo P. Determination of new bioflavonoids in bergamot (Citrus bergamia) peel oil by liquid chromatography coupled to tandem ion trap–time-of-flight mass spectrometry. Flavour Fragr J. 2014;29(2):131–6.
257. Dugo G, Bonaccorsi I, Sciarrone D, Schipilliti L, Russo M, Cotroneo A, Dugo P, Mondello L, Raymo V. Characterization of cold-pressed and processed bergamot oils by using GC-FID, GC-MS, GC-C-IRMS, enantio-GC, MDGC, HPLC and HPLC-MS-IT-TOF. J Essent Oil Res. 2012;24(2):93–117.
258. Belsito EL, Carbone C, Di Gioia ML, Leggio A, Liguori A, Perri F, Siciliano C, Viscomi MC. Comparison of the volatile constituents in cold-pressed bergamot oil and a volatile oil isolated by vacuum distillation. J Agric Food Chem. 2007;55(19):7847–51.
259. Siano F, Cautela D. Assessment of free plant sterols in cold pressed citrus essential oils. Nat Prod Res. 2021;35(21):4078–83.
260. Allaf T, Tomao V, Ruiz K, Chemat F. Instant controlled pressure drop technology and ultrasound assisted extraction for sequential extraction of essential oil and antioxidants. Ultrason Sonochem. 2013;20(1):239–46.
261. Kamal GM, Ashraf MY, Hussain AI, Shahzadi A, Chughtai MI. Antioxidant potential of peel essential oils of three Pakistani citrus species: citrus reticulata. Citrus Sinensis Citrus Paradisii Pak J Bot. 2013;45(4):1449–54.
262. Goncalves D, Costa P, Rodrigues CE, Rodrigues AE. Effect of Citrus sinensis essential oil deterpenation on the aroma profile of the phases obtained by solvent extraction. J Chem Thermodyn. 2018;116:166–75.
263. Luque-Alcaraz AG, Velazquez-Antillón M, Hernández-Téllez CN, Graciano-Verdugo AZ, García-Flores N, Iriqui-Razcón JL, Silvas-García MI, Zazueta-Raynaud A, Moreno-Vásquez MJ, Hernández-Abril PA. Antioxidant effect of nanoparticles composed of zein and orange (citrus sinensis) extract obtained by ultrasound-assisted extraction. Materials. 2022;15(14):4838.
264. Kusrini E, Mawarni D, Mamat M, Prasetyanto E, Usman A. Comparison of antibacterial activity in ethanol extract and essential oil of citrus sinensis (L.) peels obtained by sohxlet and distillation methods, IOP conference series: materials science and engineering. Springer, Cham: IOP Publishing; 2018.
265. Bouabdallah S, Cianfaglione K, Azzouz M, Batiha GE-S, Alkhuriji AF, Al-Megrin WAI, Ben-Attia M, Eldahshan OA. Sustainable extraction, chemical profile, cytotoxic and antileishmanial activities in-vitro of some citrus species leaves essential oils. Pharmaceuticals. 2022;15(9):1163.
266. Mehmood T, Afzal A, Anwar F, Iqbal M, Afzal M, Qadir R. Variations in the composition, antibacterial and haemolytic activities of peel essential oils from unripe and ripened Citrus limon (L.) Osbeck fruit. J Essent Oil Bear Plants. 2019;22(1):159–68.
267. Guadayol M, Guadayol JM, Vendrell E, Collgrós F, Caixach J. Relationship between the terpene enantiomeric distribution and the growth cycle of lemon fruit and comparison of two extraction methods. J Essent Oil Res. 2018;30(4):244–52.
268. Hirota R, Roger NN, Nakamura H, Song HS, Sawamura M, Suganuma N. Anti-inflammatory effects of limonene from yuzu (Citrus junos Tanaka) essential oil on eosinophils. J Food Sci. 2010;75(3):H87–92.
269. Hata T, Sakaguchi I, Mori M, Ikeda N, Kato Y, Minamino M, Watabe K. Induction of apoptosis by citrus paradisi essential oil in human leukemic (HL-60) cells. In vivo Athens Greece. 2003;17(6):553–9.
270. Zanganeh H, Mortazavi SA, Shahidi F, Alizadeh Behbahani B. Evaluation of the chemical and antibacterial properties of Citrus paradise essential oil and its application in Lallemantia iberica seed mucilage edible coating to improve the physicochemical, microbiological and sensory properties of lamb during refrigerated storage. J Food Measur Charact. 2021;15(6):5556–71.
271. Churata-Oroya DE, Ramos-Perfecto D, Moromi-Nakata H, Martínez-Cadillo E, Castro-Luna A, Garcia-de-la-Guarda R. Efecto antifúngico de Citrus paradisi "toronja" sobre cepas de Candida albicans aisladas de pacientes con estomatitis subprotésica. Rev Estomatol Herediana. 2016;26(2):78–84.
272. Settanni L, Palazzolo E, Guarrasi V, Aleo A, Mammina C, Moschetti G, Germanà MA. Inhibition of foodborne pathogen bacteria by essential oils extracted from citrus fruits cultivated in Sicily. Food Control. 2012;26(2):326–30.
273. Sharma S, Loach N, Gupta S, Mohan L. Evaluation of larval toxicity, mode of action and chemical composition of citrus essential oils against Anopheles stephensi and culex quinquefasciatus. Biocatal Agric Biotechnol. 2022;39: 102284.
274. Nair A, Kurup R Sr, Nair AS, Baby S. Citrus peels prevent cancer. Phytomedicine. 2018;15(50):231–7.
275. Chutia M, Bhuyan PD, Pathak M, Sarma T, Boruah P. Antifungal activity and chemical composition of citrus reticulata Blanco essential oil against phytopathogens from North East India. LWT-Food Sci Technol. 2009;42(3):777–80.
276. Kaur S, Panesar PS, Chopra HK. Standardization of ultrasound-assisted extraction of bioactive compounds from kinnow mandarin peel. Biomass Convers Biorefinery. 2021;1–1:1.
277. Anticona M, Blesa J, Lopez-Malo D, Frigola A, Esteve MJ. Effects of ultrasound-assisted extraction on physicochemical properties, bioactive compounds, and antioxidant capacity for the valorization of hybrid Mandarin peels. Food Biosci. 2021;42: 101185.
278. Jayaprakasha GK, Murthy KNC, Demarais R, Patil BS. Inhibition of prostate cancer (LNCaP) cell proliferation by volatile components from Nagami kumquats. Planta Med. 2012;78(10):974–80.
279. Al-Saman MA, Abdella A, Mazrou KE, Tayel AA, Irmak S. Antimicrobial and antioxidant activities of different extracts of the peel of kumquat (citrus japonica Thunb). J Food Measur Charact. 2019;13(4):3221–9.
280. Lin X, Cao S, Sun J, Lu D, Zhong B, Chun J. The chemical compositions, and antibacterial and antioxidant activities of four types of Citrus essential oils. Molecules. 2021;26(11):3412.
281. Quijano CE, Pino JA. Volatile compounds of round kumquat (Fortunella japonica Swingle) peel oil from Colombia. J Essent Oil Res. 2009;21(6):483–5.
282. Nouri A, Shafaghatlonbar A. Chemical constituents and antioxidant activity of essential oil and organic extract from the peel and kernel parts of Citrus japonica Thunb. (kumquat) from Iran. Nat Product Res. 2016;30(9):1093–7.
283. Lakache Z, Hacib H, Aliboudhar H, Toumi M, Mahdid M, Lamrani N, Tounsi H, Kameli A. Chemical composition antidiabetic anti-inflammatory antioxidant and toxicity activities of the essential oil of Fortunella margarita peels. J Biol Res Boll Della Soc Ital Biol Sper. 2022;95(2):1.
284. Ibrahim NA, El-Hawary SS, Mohammed MM, Farid MA, AbdelWahed NA, Ali MA, El-Abd EA. Chemical composition antiviral against avian influenza (H5N1) virus and antimicrobial activities of the essential oils of the leaves and fruits of Fortunella margarita lour. swingle growing in Egypt. J Appl Pharmaceut Sci. 2015;5(1):006–12.