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Review

Aroma Compounds of Carrier Oils

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Abstract: Carrier oils are used with essential oils to dilute and enhance skin penetration. They are composed of fatty acids, triglycerides, monoterpenes, and sesquiterpenes and are added to reduce potency and odor. Carrier oils have pharmaceutical applications and reduce cytotoxicity. Solvent extraction is a common practice in the production of industrial-scale carrier oils, but harmful to the environment, so new eco-friendly methods are being researched. This review documents the available characteristics of various carrier oils and identifies knowledge gaps for future studies.

Keywords: carrier oil; volatile organic compounds; fatty acids; extraction methods

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1. Introduction

Carrier oils, which include vegetable or seed oils, are used in conjunction with essential oils to dilute, reduce potency, and enhance penetrating the skin by breaking down the lipids in the stratum corneum [1]. Carrier oils mainly comprise fatty acids, triglycerides, monoterpenes, and sesquiterpenes, allowing for enhanced penetration of the stratum corneum [1]. Carrier oils typically have fewer volatile compounds than essential oils and so absorb into the skin before they can evaporate and typically also have a less potent odor [2,3]. Carrier oils absorb many biologically active compounds and have promising pharmaceutical applications in the delivery of drugs through the skin. The addition of carrier oils to essential oils has been found to reduce the cytotoxicity of essential oils and even give the oil an antimicrobial effect [4]. Generally, small-scale extractions of carrier oils are performed using steam or hydrodistillation, while industrial-scale extractions generally use solvent extraction or mechanical press methods [1]. Solvent extraction typically utilizes a Soxhlet apparatus using *n*-hexane as a solvent, which results in very high oil extraction yields. However, the use of *n*-hexane is environmentally harmful and typically requires additional refinement steps for the extracted oil which might remove important bioactive compounds and alter the overall chemical composition [5–7]. The United States Environmental Protection Agency (EPA) has labeled *n*-hexane as a hazardous air pollutant and so solvent extraction using this solvent has become a less desirable extraction method in recent years despite the high oil extraction yield [7]. Environmental concerns have prompted research into new methods of oil extraction that are safe for the environment, high-yielding, able to maintain the chemical composition of the oil, and are cost-effective. Some of these methods include supercritical fluid extraction, microwave-assisted extraction, ultrasound-assisted extraction, and many other techniques. Seed oils extracted from vegetables are comprised almost entirely of triacyl glycerides making up 95 to 98% of the total chemical composition [8]. However, the remaining percentage likewise contributes to the biological activity of the oils and consists of sterols, tocopherols, phenols, and other compounds [8].

Though there exist large amounts of literature on the many different carrier oils, there are many in which important information such as the chemical composition, the volatile organic compounds (VOCs), the industrial production methods, extraction methods, and the origin are not documented or are hidden in obscure pieces of literature. The goal of this review is to consolidate the large amounts of information on carrier oils. This review seeks to document the characteristics of the following carrier oils: almond, apricot, argan, avocado, babassu, baobab, black cumin seed, Brazil nut, camelina, castor, chia seed, coconut, cranberry seed, grapeseed, hazelnut, hemp seed, jojoba, kukui nut, macadamia nut, marula, moringa, neem seed, olive, palm kernel, passionfruit seed, pomegranate seed, evening primrose, pumpkinseed, raspberry seed, rosehip, sacha inchi, safflower, sea buckthorn, sesame seed, shea butter, soybean, sunflower, and tamanu. This will identify the gaps in knowledge that exist in the literature regarding the listed carrier oils to guide future studies (Figure 1). The evaluation of different extraction methods included in this review will expectantly provide guidance for future research into new extraction methods.

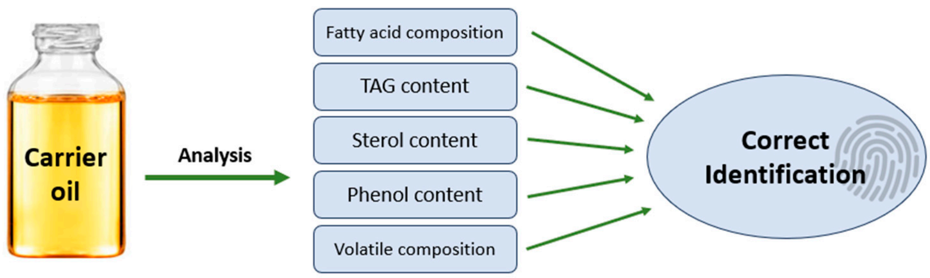

Figure 1. A summary of the information used for carrier oil authentication.

2. Methodology

The composition of carrier oils was researched through a literature search through electronic databases such as Google Scholar, SCI Finder, PubMed, and ScienceDirect for information on various oils including almond, apricot, argan, avocado, babassu, baobab, black cumin seed, Brazil nut, camelina, castor, chia seed, coconut, cranberry seed, grapeseed, hazelnut, hemp seed, jojoba, kukui nut, macadamia nut, marula, moringa, neem seed, olive, palm kernel, passionfruit seed, pomegranate seed, evening primrose, pumpkinseed, raspberry seed, rosehip, sacha inchi, safflower, sea buckthorn, sesame seed, shea butter, soybean, sunflower, and tamanu. The search involved using various keywords such as "origin", "extraction method", "fatty acid composition", and "volatile composition".

3. Almond Oil

Almonds trees, or *Prunus dulcis* D.A. Webb (syn. *Prunus amygdalus* Batsch) of the Rosaceae family, are believed to have originated in Central Asia [9]. Almond trees are grown primarily in Mediterranean climates such as Morocco and Spain but are also grown in France, Argentina, and the USA [10,11]. As of 2011, California was responsible for 84% of the world's almond production producing 2.02 billion pounds of almonds [12]. Almond oil has historically been used in ancient medicine. Chinese, Ayurvedic, and Greco-Persian schools of medicine utilized almond oil throughout history for its uses in health and beauty [13]. Almond oil is produced by first dehulling almonds and drying them out. Once the almonds are dried out, the shell must be separated from the almond seed. Then the almond oil is extracted from the almond. Industrial methods of almond oil extraction sometimes involve using solvents and high temperatures to produce a high oil yield [14]. However, these methods can diminish the quality of the oil and often require the oil to undergo a refining process which can diminish the health benefits of raw almond oil by removing or inactivating the vitamins and other natural elements. The supercritical fluid extraction method is a common way to avoid harsh solvents and temperatures which would diminish the almond oil [14].

Other methods of extraction which prevent the diminishing of vitamins and other natural elements include a variety of mechanical methods such as cold-press extraction or hydraulic-press extraction [15]. Screw-press extraction is the preferred method over hydraulic-press extraction as screw-pressing produces higher yields and can be a continuous process which is favored for industrial-scale oil extraction [11,16]. Oleic acid usually comprises 50–70% of total fatty acids in almond oil [11]. According to Roncero et al., 95% of the fatty acids in almond oil consist of palmitic acid (5.2–6.7%), palmitoleic acid (0.3–0.6%), stearic acid (0.2–1.7%), oleic acid (57.5–78.7%), and linoleic acid (12.0–33.9%) [14]. Wild almond seed oils contained palmitic acid (6.9%), palmitoleic acid (0.3%), stearic acid (3.3%), oleic acid (67.2%), linoleic acid (22.1%), and saturated fatty acids (10.2%) [17]. The volatile organic compounds in almond oils were mainly aldehydes, alcohols, carboxylic acids, furans, ketones, lactones, pyrazines, and terpenes [18].

4. Apricot Seed Oil

Apricot (*Prunus* L., Rosaceae) originated from Asia [19]. *P. armeniaca* L. is the most common species of apricot cultivated for fruit production [19]. Apricot trees are cultivated and harvested in several Mediterranean and Central Asian countries with Turkey being the largest producer of apricots and Uzbekistan being the second largest producer [20,21]. The oil from apricot kernels has been used historically in oriental medicine to treat a variety of skin diseases [22]. Prior to oil extraction, the apricot seed coating must be removed, and the seeds must be made into a powder typically by crushing with the use of a blender [23]. Apricot seed oil is most commonly extracted through solvent extraction or with the use of a cold press. Still, it can also be extracted by enzyme-assisted extraction or supercritical fluid extraction [5,21]. Cold-press extraction was shown to have a lower yield than solvent extraction methods, but the fatty acid content, triacyl glyceride content, phenol content, and color of the oil showed no significant differences between the different methods [24]. However, tocopherol content, antioxidant activity, and oxidative stability had significant differences between the two methods [24].

Industrial-scale processing of apricot seed oil typically involves organic solvent extraction as this method of extraction results in high yields. This method is also less expensive and requires less maintenance than cold-press extraction [5]. *n*-Hexane is a commonly used solvent in the extraction of apricot seed oil, though the use of this solvent brings about several safety and environmental concerns [5,6]. Oleic acid comprises 62.3–80.9% of the total fatty acids in apricot seed oil [25,26]. The fatty acid composition of the wild apricot kernel oil was dominated by unsaturated fatty acids (92.9%), specifically oleic acid (74.8%), followed by linoleic acid (17.4%) and palmitic acid (4.7%) [27]. The fatty acid composition varied for different harvest times [28]. Sterols ranged from 215.7 to 973.6 mg/100 g oil, and squalene (12.6–29.6 mg/100 g oil) in apricot kernel oils from various varieties [29]. The tocopherol content of apricot kernel oils ranged from 24.18–64.98 mg/kg [28]. Benzaldehyde (22.23–22.85%), benzyl alcohol (15.13–15.35%), 2-methyl-propanal (15.03–15.09%), 1,3-dimethyl-benzene (5.12–5.18%), ethylbenzene (3.23–3.58%), 1,2,4,5-tetramethyl-benzene (3.26–3.55%), 2-ethyl-1,3-dimethyl-benzene (3.16–3.53%), 1,2,3,5-tetramethyl-benzene (2.46–2.47%), 1-phenyl-1,2-propanedione (2.2–2.23%), and *o*-cymene (0.37–2.91%) were reported as the major volatiles of the unrefined apricot kernel oil [30].

5. Argan Oil

Argan oil is produced in southwestern Morocco as it is the only area where *Argania spinosa* Skeels, more commonly known as argan, is endemic and naturally grows [31,32]. The argan tree also grows in the Tindouf region of Algeria, though the tree is not endemic to Algeria [33]. The production of argan oil used to be limited both in quality and yield due to the persistence of traditional extraction methods historically used in southwestern Morocco. However, these extraction methods have been improved using a cold-press extraction method [34]. Modern methods of argan oil extraction begin first with the picking and drying of the fruit from argan trees. Dehulling, collecting the kernels, and possibly roasting depending on the intended use of the oil, before finally being cold pressed to extract the argan oil [34]. The industrial extraction of argan oil is typically performed by solvent extraction using a lipophilic solvent such as hexane [32]. The fatty acid composition of argan oil was oleic acid (45.0–50.3%), linoleic acid (29.0–36.8%), palmitic acid (12.3–13.8%), stearic acid (4.7–5.7%), arachidic acid (0.3–0.4%), gadoleic acid (0.3–0.4%), myristic acid (0.2%), linolenic acid (0.1–0.2%), and palmitoleic acid (0.1%) [34,35]. The volatile organic compounds in argan oils were primarily made of alcohols, pyrazines, acids, furans, pyrroles, lactones, phenols, ketones, and aldehydes [36]. The squalene content of argan oil ranged from 303–321 mg/100 g while the total sterols were in the range of 272–357 mg/100 g [37].

6. Avocado Oil

Avocado fruit, or *Persea americana* Mill. of the Lauraceae family, originated from Southern Mexico where the trees have been cultivated since ancient times up to 6000 years ago [38]. Modern-day avocado oil production takes place mainly in New Zealand, Mexico, Chile, South Africa, and the United States [39]. Avocado oil has been popularized due to its use in skin care and human nutrition [40]. Avocado oil is unique in that it is absorbed by the skin far easier than almond, corn, olive, and soybean oils, making it an ideal oil for skin care [40]. Avocado oil has been used historically as far back as the sixteenth century when it was used in the treatment of scars and rashes [40]. The bioactive compounds of virgin avocado oil, notably α-tocopherol and β-sitosterol, assist in reducing cholesterol and hypertension [41]. The most common way that avocado oil is produced is through solvent extraction [42]. Avocado oil production starts with the drying of the fruit to remove any water. The dried avocado fruit is then crushed and ground into a powder [43]. The powder is exposed to hexane in an extractor, and the oil is separated from the powder [42].

Traditional methods of extraction typically involve the use of organic solvents on dried avocado fruit tissue, but mechanical methods are also a common method of extraction due to the lack of harsh solvent use and because the technology required is less expensive [42]. Solvent extraction utilizes an organic solvent, most commonly hexane, to extract avocado oil from either the seed or the fruit [42]. This method is common as the oil yield from fruit is around 95% [38]. Cold-pressing is a common mechanical method of avocado oil extraction that uses a screw-press to squeeze out avocado oil from the tissues at temperatures below 50 °C to maintain the chemical composition of the oil [42]. Avocado oil is typically extracted on an industrial scale through cold-pressing [41]. Unlike most other carrier oils, avocado oil is typically extracted from rejected avocado fruit [40]. The typical fatty acid composition of avocado oil is oleic acid (65.4–67.7%), linoleic acid (13.5–15.2%), and palmitic acid (12.8–13.4%) [43,44]. The total phytosterol of avocado oil was 339.6 mg/100 g [39]. The major volatile compounds from avocado fruit oil from Cuba were (*Z*)-nerolidol (3.89 mg/kg), (*E*,*E*)-α-farnesene (0.65 mg/kg), β-caryophyllene (0.64 mg/kg), (*E*,*E*)-2,4-decadienal (0.58 mg/kg), caryophyllene oxide (0.50 mg/kg), α-copaene (0.35 mg/kg), (*Z*)-3-hexenol (0.23 mg/kg), *allo*-aromadendrene (0.21 mg/kg), germacrene D (0.18 mg/kg), δ-cadinene (0.18 mg/kg), (*E*,*E*)-farnesyl acetate (0.16 mg/kg), limonene (0.15 mg/kg), hexadecanoic acid (0.13 mg/kg), (*E*)-β-ocimene (0.12 mg/kg), guaiol (0.12 mg/kg), 9-*epi*-(β)-caryophyllene (0.11 mg/kg), and 10-undecenal (0.10 mg/kg) [45].

7. Babassu Oil

Babassu palms encompass a group of palms native to Brazil and are associated with palms of many different scientific names coming from the Arecaceae family and *Orbignya* and *Attalea* genera [46–48]. However, babassu palms are most commonly associated with the species *Attalea speciosa* Mart. (syn. *Orbignya phalerata* Mart.), which is found in the Amazonian regions of the north and northeastern states of Brazil [48,49]. The seeds or almonds are obtained from the babassu palm fruit and used for industrial-scale extractions of babassu oil [50]. Industrial scale babassu oil extraction using the hot oil extraction method is commonly performed in Brazil [50]. The main fatty acids were lauric acid (47.4–54.7%), myristic acid (11.8–15.6%), oleic acid (11.3%), palmitic acid (8.0%), caprylic acid (6.2%), capric acid (5.8%), stearic acid (3.2%), and linoleic acid (1.9%), with a total of saturated fatty acids of 86.42% [49]. The fatty acid composition of babassu oil as lauric acid (54.7%), myristic acid (11.8%), capric acid (9.6%), caprylic acid (9.2%), oleic acid (6.5%), palmitic acid (4.8%), caproic acid (3.3%), stearic acid (2.1%), and linoleic acid (0.9%), with a total of unsaturated fatty acids of 9.5% [51].

8. Baobab Oil

Adansonia digitata L., commonly known as Baobab, is found throughout tropical regions of Africa, islands in the Indian and Atlantic Oceans, and even in some parts of southern Arabia [52,53]. The crude oil extraction of baobab oil starts with the picking of the fruit and the removal of its shell [54]. The pulp is separated from the seeds of the fruit and the seeds are pressed using a mechanical method such as a cold press [54]. Mechanical and solvent methods of extraction of baobab oil were compared and it was found that mechanical methods, more specifically the cold-pressing extraction method, better maintained the physicochemical properties of the oil and preserved the high concentrations of phenolic compounds [55]. It was also suggested that the physicochemical properties of the oil were less impacted by the solvent extraction method when a mixture of acetone and hexane was used rather than either solvent alone [55]. Baobab has high percentages of palmitic and oleic acids which makes it ideal for use in cosmetic products [56]. The oil is mainly made of oleic acid (23.3–36.1%), linoleic acid (29.0–30.6%), palmitic acid (21.9–22.9%), and stearic acid (3.7–5.9%), and a total sterol content of 4630 mg/kg [55,57,58].

9. Black Cumin Oil

Nigella sativa L., more commonly known as black cumin, is cultivated in India but is also grown in Egypt, Syria, Lebanon, Israel, and a variety of Mediterranean countries in Southern Europe [59,60]. It is native to Africa, the Mediterranean, and Southwest Asia [61,62]. In the Middle East, black cumin was used in ancient medicine for a large variety of different ailments [61]. The volatile oil of black cumin has high concentrations of thymoquinone, which has been shown to provide a variety of health benefits mainly due to the free radical scavenging effects which provide the oil's antioxidative properties [59]. The preparation of black cumin seeds for black cumin oil extraction by solvent methods starts with the separation of seeds that are either contaminated or too small for extraction, using a sieve [63]. For the supercritical fluid extraction method, the seeds are dried and then crushed into a powder using a stainless-steel grinder [63]. The sample preparation for most methods of black cumin oil extraction involves drying and grinding the seeds while varying the temperatures depending on the extraction technique [63]. Black cumin oil is commonly extracted using solvent extraction but is also extracted through cold-pressing when it is necessary to avoid hazardous solvents which could alter the oil's composition [62]. *N. sativa* seed oil was dominated by 9-eicosyne (63.04%) followed by linoleic acid (13.48%), palmitic acid (9.68%), *p*-cymene (2.54%), and thymoquinone (1.86%) when analyzed by GC-MS [64]. The major fatty acids of black cumin seed oil were (*Z*)-linoleic acid (427.8 g/kg), (*Z*)-oleic acid (294.3 g/kg), palmitic acid (83.8 g/kg), (*Z*)-pentadecanoic acid (63.6 g/kg), linolenic acid (42.1 g/kg), and stearic acid (22.6 g/kg), with a total of 81% unsaturated fatty acids [65]. According to [28] and [62], the fatty acid compositions of black cumin seeds were dominated by linoleic acid (40.3–58.9%), oleic acid (18.7–28.1%), and palmitic acid (10.1–12.5%). The tocopherol content of black cumin seeds ranges between 9.15 and 24.65 mg/100 g, and the sterol content was 1993.07 and 2887.28 mg/kg [28]. The main volatiles in black cumin seed extract were thymoquinone (21.01%), *o*-cymene (18.23%), β-thujene (17.22%), *cis*-4-methoxy thujane (7.04%), longifolene (6.43%), β-pinene (5.08%), d-limonene (3.46%), (*E*)-longipinene (2.19%), 2-methyl-5-(1-methylethyl)-phenol (2.07%), and 3-cyclohexene-1-carboxaldehyde (1.69%) [66].

10. Brazil Nut Oil

Brazil nuts (*Bertholletia excelsa* Humb. & Bonpl.) originate from the northern and eastern regions of the Amazon rainforest in Brazil and have expanded to several other South American countries including Bolivia, Columbia, Peru, and Venezuela [67]. The Brazil nuts or seeds are gathered from Brazil nut trees and then dehydrated and prepared for oil extraction [68]. The drying process is very important as Brazil nuts have a high moisture content which can lead to fungal growth [69]. The Brazil nuts which are broken or too small to be sold commercially are used in the extraction of Brazil nut oil [70]. Brazil nuts can be extracted by using *n*-hexane and ethanol as solvents in a Soxhlet apparatus or through the use of hot or cold pressing to better retain the bioactive compounds of the oil [68,71]. Hydraulic press extraction, solid–liquid (solvent) extraction by petroleum ether and hexane as the solvent, and supercritical fluid CO_2 extraction were compared, and it was found that supercritical fluid CO_2 extraction resulted in the highest average percentage of rich unsaturated fatty acids [71]. Industrial-scale extraction of Brazil nut oil typically involves mechanical methods such as hot pressing or cold pressing using a hydraulic press [68,71]. The major fatty acids of Brazil nut oil were linoleic acid (42.8%), oleic acid (29.1%), palmitic acid (13.5%), and stearic acid (11.8%) [72,73]. The total phenolic and total flavonoids of the oil were 169.2 and 107.8 mg/100 g, respectively [72,73]. β-Sitosterol accounts for 76% of the sterol composition and β-tocopherol 88–93% of the tocopherol content of Brazil nut oils [74]. The volatiles of Brazil nut oil were a mixture of carbonyls, alcohols, hydrocarbons, and terpenes [75].

11. Camelina Oil

Camelina has the highest species diversity in Turkey and the Caucasus regions which hints at those areas being its place of origin [76]. However, that is not the only hotspot for *Camelina* species diversity [77]. In Russia and Ukraine, the high camelina species diversity suggests that it is likely to have been the origin of camelina [77]. Camelina (*Camelina sativa* L.) was first cultivated during the bronze age in which northern Europeans used the plant primarily for oil, which was used in medicine, as nutrition, and as a fuel source. Camelina plants grow quickly, can self-pollinate, and are over 40% oil in composition, making them an ideal oil crop [78]. The traditional process of camelina oil extraction begins with the harvesting of the dried plants. The seeds are collected from the dried plants, cleaned, and then milled into a powder. Water is added to the powder to make a paste and then heated again. This paste is then used in the extraction of camelina oil [79].

Mechanical extraction, solvent extraction, and enzymatic extraction are some of the most common methods of camelina oil extraction [80]. Mechanical extraction was traditionally used in the extraction of camelina oil by use of a hydraulic or screw press. This method, however, does not result in as high a yield as other methods of extraction such as solvent extraction, but the refinement process is much simpler as only filtration and degumming are required to refine camelina oil for human consumption. Solvent extraction results in higher oil extraction yields than mechanical or enzymatic extraction methods but is more harmful to the environment and requires refinement to remove any solvent in the oil. Enzymatic extraction is a method that results in high oil extraction yields and does not require the use of harsh solvents or refinement processes. However, this method takes much longer to extract than both mechanical and solvent methods of extraction. Solvent extraction is the preferred method of camelina oil extraction on an industrial scale due to the high oil yields and to avoid economic losses due to waste in mechanical extraction [79]. Using a Soxhlet apparatus and hexane as the solvent was found to result in camelina oil yields of 30.5% by weight, making it a profitable method of extraction on an industrial scale [80]. The major fatty acids of camelina oil were α-linolenic acid (34.7–37.1%), oleic acid (14.8–19.1%), linoleic acid (15.3–19.3%), gondoic acid (11.7–16.7%), palmitic acid (4.8–6.4%), and stearic acid (1.6–2.9%) [81,82]. A total of 168 volatile and semi-volatile compounds were identified in camelina seeds between acids, alcohols, esters, phenolics, aldehydes, ketones, alkanes, alkenes, aromatics, ethers, and terpenes [79].

12. Castor Oil

Castor oil (*Ricinus communis* L.) contributes to only around 0.15% of the world's vegetable oil production but is, more importantly, used in the production of chemicals due to the oil being the only commercially available source of a hydroxylated fatty acid, ricinoleic acid, which comprises that majority of castor oil (75.7–94.6%) [83–85]. The exact origins of castor are unknown, though four regions are believed to be the possible origin of castor. These regions are East Africa, Northwest and Southwest Asia and the Arabian Peninsula, India, and China [86]. In modern times, castor is now grown all over the world in tropical, sub-tropical, and even temperate climates [86–88]. India is currently the largest producer of castor oil and castor seeds with an annual production between 250,000 and 350,000 tons of castor oil [83]. Castor seed consists of anywhere between 30 and 50% oil by mass. The first step of castor oil production, right after harvesting, begins with the drying of the seeds so that their hulls can be cracked open, and the seeds isolated from the hulls. After the seeds are isolated, they are cleaned so that any other foreign matter is removed. A steam-jacketed method is used to heat the seeds and dry them before they are finally used in the extraction of castor oil [83]. The extraction of castor oil is performed by a variety of different methods including hydrate press extraction, continuous screw-press extraction, solvent extraction, or even a combination of mechanical hot-press extraction and solvent extraction to result in a high oil extraction yield [88]. Crude castor oil must be subjected to a refinement process to extend the storage life of the oil by removing impurities that could contribute to the oil's deterioration [83]. Colloidal matter, phospholipids, and excess free fatty acids are just some of the impurities removed by castor oil's refinement process [83].

13. Chia Seed Oil

Salvia hispanica L., belonging to the Lamiaceae family and more commonly known as chia, originates from Mexico and Guatemala but can be grown in nearly every continent [89–91]. Chia has been used for human nutrition for about 5500 years and was used as a medicine by the Aztec and Mayan peoples [92]. Chia seeds contain around 40% oil which contains high concentrations of essential fatty acids, ω-3 α-linolenic acid, and ω-6 linoleic acid [93]. The ingestion of chia seeds, along with chia seed oil, has been shown to result in health benefits for cardiovascular diseases, diabetes, and metabolic syndrome [92]. Chia also has high concentrations of phytosterols for an oil seed crop, which has cancer and cardio-protective effects [92]. The European Parliament declared chia a Novel Food in 2019 and found that the ingestion of chia seeds had resulted in no identifiable health hazards. A common process of chia seed preparation for oil extraction begins with the removal of any foreign matter or seeds that are not mature enough for extraction by using a sieve. The seeds are further cleaned and then ground down to a fine powder before finally being used in the extraction of chia seed oil. The extraction of chia seed oil was found to yield more than 30% more oil by solvent extraction than by pressing [94]. It was also found that the fatty acid content had no significant differences between the two methods of extraction [94]. Traditional methods of chia seed oil extraction typically involve the use of an expeller for mechanical methods or solvent extraction using *n*-hexane [95]. However, the current method of industrial-scale chia seed oil extraction is performed through cold pressing. The main fatty acids of chia seed were linolenic acid (60.5%), linoleic acid (22%), oleic acid (7.4%), palmitic acid (7.3%), and stearic acid (2.8%) [96].

14. Coconut Oil

The Indo-Malayan tropical regions are believed to be the origin place of the coconut palm (*Cocos nucifera* L.). However, the coconut palm has spread to most tropical regions of the world largely thanks to European and Polynesian exploration and cultivation [97]. Indonesia is the largest producer of coconuts followed by the Philippines and India [98]. Coconut oil is one of the oldest oils with its use being traced as far back as 4000 years ago [99]. Lauric acid comprises about half (49.6–51.5%) of the total fatty acids present in coconut oil [100,101] and is a precursor to monolaurin, which has many health benefits along with antiviral, antibacterial, and antiprotozoal monoglyceride properties [102]. The process of coconut oil extraction through low-pressure methods starts with the procurement of coconut meat, which is grated and dried to an 11% moisture content. The dried coconut gratings are placed in a low-pressure press to extract the oil, which is collected, and later filtered, and centrifuged [103]. Coconut oil can also be extracted using a cold press in which the coconut meat is grated, but rather than drying the grated coconut, water is added to the gratings. The gratings are then placed in mesh bags where the coconut milk is squeezed out, collected, and then left to sit for a day. After a day has passed, the coconut milk gets separated into three distinct layers. The middle layer is collected, filtered, and left to sit for 72 h so that any water can evaporate. Coconut oil can also be extracted in a variety of other ways, including chilling, freezing, and thawing methods. These methods start with pressing coconut kernel and collecting the residue. Pressure is applied to the residue, and the emulsion is extracted and then centrifuged [103]. Centrifugation separates the residue into distinct layers in which the coconut cream layer is collected. Enzymes are added to the coconut cream, and it is frozen, thawed, and then centrifuged. Hot-press and cold-press extraction have been traditionally used to extract coconut oil. However, both methods result in low oil yields, and the hot press method will alter the chemical composition of the oil, compromising the important bioactive compounds [103]. It was found that coconut oil contains much lower sterol content than most other vegetable oils, including soybean oil and corn oil [100]. Ethyl acetate, acetic acid, hexanal, 2-heptanone, limonene, nonanal, octanoic acid, ethyl octanoate, δ-octalactone, δ-decalactone, and dodecanoic acid were identified as the volatile compounds in virgin coconut oil [104].

15. Cranberry Seed Oil

Cranberries are believed to have originated in North America but are also grown and cultivated in Europe [105]. The European cranberry (*Vaccinium oxycoccos* L.) and the American cranberry (*Vaccinium macrocarpon* Aiton) are rich sources of bioactive compounds which include anthocyanins, proanthocyanins, and quercetin [106]. These bioactive compounds have several health benefits due to the antioxidant activity of the cranberry fruit, especially a cardioprotective effect. These compounds are important as they decrease the risk of cardiovascular disease by reducing low-density lipoprotein cholesterol oxidation, inhibiting platelet aggregation, and reducing blood pressure [107]. Cranberry seed oil is extracted from cranberry seeds, which are typically procured as a by-product from the fruit juice processing [108]. The cold-pressing extraction technique, along with ultrasonographic extraction, are common methods of cranberry oil extraction as the chemical composition and bioactive compounds are not significantly altered or diminished [105]. It was found that ultrasound assisted extraction, when compared with microwave assisted extraction, heat reflux extraction, and cold-press extraction, produced the highest cranberry oil yield and the highest tocopherol concentrations, revealing that ultrasound assisted extraction produced the highest quality oil which was most rich in phytonutrients [108]. Traditional methods of cranberry oil extraction include cold-press extraction and heat-reflux extraction. However, these methods are being improved upon and replaced by microwave assisted extraction and ultrasound assisted extraction due to these methods resulting in an increase in oil yield and a higher tocopherol concentration [108]. Linoleic acid (37.4%), linolenic acid (34.9%), oleic acid (20.2%), and palmitic acid (5.3%) were the main fatty acids in cranberry seed oil [105]. The volatile organic compounds from cranberry seed oil were 1,2-dimethyl cyclopropane, 1,3,5,7-cyclooctatetraene, 1-penten-3-one, (*E*,*E*)-2,4-heptadienal, (*E*)-2-butenal, (*Z*)-2-heptenal, 2-hexenal, (*E*)-2-penten-1-ol, 2-pentenal, (*E*)-2-pentene, (*Z*)-4-heptenal, acetic acid, ethyl acetate, 2-ethylfuran, furfural, hexanal, hexane, (*S*)-methyl-oxirane, pentanal, and trimethylene oxide [109].

16. Grapeseed Oil

Grape refers to any plant in the *Vitis* genus, which comprises deciduous flowering plants that produce berries [110]. One of the most common species of grape is *Vitis vinifera* L., or the European grape, which is native to the Mediterranean and Central Asia [110]. It is believed that grape cultivation originated in the foothills of the Caucasus Mountains along with regions in the Middle East [111]. As of 2018, China, France, and the United States were the largest producers of grapes [110]. The wine-making industry produces grapeseed oil or grape seeds themselves as a by-product, which the grape seeds can later be used to produce grapeseed oil [112]. Grape seeds contain only 8–20% oil, so the extraction method used is important as the yields will vary [112]. Three common methods of grapeseed oil extraction, screw-press extraction, supercritical CO_2 extraction, and a combination of the two called gas-assisted mechanical expression (GAME), were compared for their yield and polyphenol content [113]. It was found that screw-press extraction was the most efficient process, which resulted in the highest yield. However, supercritical CO_2 extraction gave the largest amount of polyphenol co-extraction [113]. On an industrial scale, grapeseed oil is produced by first separating the seeds from the fruit, cleaning them, and then drying them out [114]. The dried seeds are later crushed and pressed to produce grapeseed oil, which is refined to allow for human consumption [114]. Linoleic acid dominates the fatty acid composition of grapeseed oil (60.9–74.7%) [112]. The total amount of tocopherols per kilogram of grapeseed oil was comparable to cotton seed oil but slightly lower [115]. The volatiles of Cabernet grapeseed oil were isoamyl acetate (27.3%), ethyl octanoate (10.3%), phenylethyl alcohol (8.8%), phenylethyl acetate (8.6%), ethyl heptanoate (7.8%), hexanoic acid (6.9%), isoamyl alcohol (5.0%), nonanal (3.7%), octanal (2.7%), and isovaleric acid (2.2%) [116]. Gamay grapeseed oil had isoamyl acetate (28.5%), ethyl octanoate (10.7%), phenylethyl acetate (7.7%), ethyl heptanoate (6.8%), hexanoic acid (5.6%), octanal (5.2%), phenylethyl alcohol (3.3%), octanoic acid (2.8%), nonanol (2.1%), nonanal (2.1%), and decanal (2.0%) as the main volatile compounds [116]. The main volatile compounds of Kalecik Karasi grapeseed oil were isoamyl acetate (30.8%), ethyl octanoate (16.5%), ethyl heptanoate (9.1%), phenylethyl acetate (8.4%), ethyl laurate (3.2%), hexanoic acid (3.1%), phenylethyl alcohol (3.1%), heptanoic acid (3.1%) [116]. Isoamyl acetate (16.1%), ethyl octanoate (26.0%), and ethyl laurate (4.3%) were the major volatile compounds in Okuzgozu grapeseed oil [116]. The volatiles of Senso grapeseed oil were isoamyl acetate (36.6%), ethyl heptanoate (12.2%), ethyl octanoate (11.7%), phenylethyl acetate (6.9%), phenylethyl alcohol (5.5%), isovaleric acid (3.6%), hexanoic acid (2.7%), and nonanal (2.0%) [116].

17. Hazelnut Oil

Hazelnut (*Corylus avellana* L.) naturally grows in Europe, Africa, the Caucasus Mountains, and eastern Asia [117]. Hazelnuts are the third most produced nut in the world by mass, with over 863,000 tons of hazelnuts produced every year. Over half of the world's hazelnut production comes from Turkey, with the rest coming from a variety of countries, including Italy, Azerbaijan, the United States, and China [118]. After hazelnuts are harvested, the skin is peeled away, and the nut is crushed and ground into a powder or paste, which is heated and dried before being used in the extraction of hazelnut oil [119]. Traditional methods of extraction, those being mostly mechanical or solvent extraction, resulting in low yields, are less environmentally friendly, are time-consuming, and often require a refining process which removes important bioactive compounds [120]. Modern methods of extraction include supercritical CO_2 extraction, enzymatic extraction, microwave-assisted extraction, and ultrasonic-assisted extraction, and have greatly improved the production of hazelnut oil by increasing the oil yield, reducing extraction times, reduced alteration in chemical composition, and reducing the risk of harming the environment [120]. The industrial chemical refinement of hazelnut oil was found to not cause any significant changes to the fatty acid composition. The sterol content, however, was greatly diminished. The tocopherol content was found to be reduced as well, but not significantly [121]. Hazelnut seeds themselves are high in the amino acids arginine, leucine, isoleucine, phenylalanine, and valine [122]. Hazelnut oil is a rich source of oleic acid (72.8–83.5%) [123].

18. Hemp Seed Oil

Hemp (*Cannabis sativa* L.) was first cultivated in China roughly 10,000 to 12,000 years ago. It is most likely that China was also the country of origin for hemp [124]. Hemp seed oil can be extracted from both whole and dehulled hemp seeds [125]. As with most seed preparations for oil extraction, hemp seeds are harvested, cleaned, dried, and then ground into a powder [126]. Supercritical CO_2 extraction, Soxhlet extraction, and cold-press extraction of hemp seed oil were compared to determine the fatty acid and tocopherol richness of their resulting oils [127]. It was discovered that the fatty acid content was mostly unchanged between the three methods. However, supercritical CO_2 extraction resulted in the highest tocopherol concentrations [127]. Microwave treatment of hemp seeds has also been shown to improve the yield of hemp seed oil and to reduce the rate of oil degradation due to enzymes by increasing the tocotrienol concentrations which are released from membranes broken down by microwave heating [126]. The traditional methods of hemp seed oil extraction involve pressing or solvent extraction, but it is becoming increasingly common for other, more advanced methods, such as microwave-assisted extraction and supercritical fluid extraction, to be used on an industrial scale [126,127]. The main fatty acids of hempseed oil were linoleic acid (53.4–56.6%), linolenic acid (15.1–19.4%), oleic acid (9.9–15.6%), palmitic acid (5.9–6.7%), and stearic acid (2.7–3.2%) [126]. β-Myrcene (37.2–61.3%), α-pinene (4.0–14.6%), β-pinene (2.4–5.7%), limonene (0.2–5.3%), (*Z*)-β-ocimene (2.4–27.8%), (*Z*)-caryophyllene (3.5–7.8%), (*Z*)-3-hexen-1-yl acetate (1.6–52.6%), and 4-methyl-3-(1-methylethylidene) cyclohexene (0.1–17.1%) were the main volatile organic compounds of hempseed oil [128].

19. Jojoba Oil

Jojoba (*Simmondsia chinensis* C.K. Schneid.) is a shrub native to the Sonoran and Mojave Deserts in the southwestern part of the United States [129]. Some of the preparation for the jojoba seeds for the extraction of jojoba seed oil involves cleaning, dehulling, crushing, flaking, and cooking [130]. Typical methods of jojoba oil extraction include mechanical extraction, solvent extraction, or mechanical extraction, followed by solvent extraction in a method called pressing and leaching [130,131]. Industrial extraction of jojoba oil typically involves mechanical extraction followed by solvent extraction using hexane to result in less oil being lost in the left-over cake from pressing. Supercritical CO_2 is a very promising method of extraction that is more environmentally friendly than solvent extraction and still results in high oil yields [132]. The main fatty acids derived from jojoba oil were eicos-11enoic acid (71.3%), docos-13-enoic (13.6%), and octadec-9-enoic (10.1%) [133,134]. Fatty acids, long-chain fatty alcohols, wax esters, sterols, and tocopherol compositions in jojoba oil varied between the Egyptian and the American oils [135]. The Egyptian oil was mainly made of gondoic acid (60.0%), erucic acid (11.8%), oleic acid (14.5%), linoleic acid (8.7%), palmitic acid (2.5%), and nervonic acid (1.6%), while the oil from Arizona had gondoic acid (67.8%), erucic acid (18.9%), oleic acid (10.8%), palmitic acid (1.2%), and nervonic acid (1.3%) [135].

20. Kukui Nut Oil

The kukui nut tree (*Aleurites moluccanus* Willd., Euphorbiaceae) is native to many islands in the Pacific Ocean due to Polynesian exploration and cultivation of the tree. The kukui nut was very important to native Hawaiian people as it was believed to have important medicinal properties. They also used the nut and its oil as a fuel source for light and as food [136]. The kukui nuts are ground into a powder, even with the shell still attached, and then dried prior to oil extraction [137]. Linoleic acid (61.6%) is the main fatty acid in kukui oil, followed by oleic acid (17.0%), linolenic acid (5.2%), stearic acid (4.7%), and palmitic acid (2.1%) [137]. No information was found about the volatile composition of the oil.

21. Macadamia Oil

Macadamia (*Macadamia* spp., Proteaceae) nuts originate from the New South Wales and Queensland states of Australia [138]. In modern times, Hawaii has been a major producer of macadamia nuts along with Australia [139]. Macadamia nut oil, when refined by traditional methods, turns rancid quickly and has important storage requirements [140]. Cold-pressed extraction is the preferred method of macadamia nut oil extraction, as other methods, such as solvent extraction, can diminish the quality of the oil and are also less safe to extract [141]. On a commercial level, macadamia nut oil is extracted either by solvent extraction or through pressing. For seeds with low oil yields, the preferred method is solvent extraction, whereas for seeds with high oil yields, the preferred method is through pressing. Macadamia nuts have high oil yields, which makes pressing a more common method of extraction on an industrial scale. However, it was found that cold-pressing, followed by solvent extraction of the seed oil cake, resulted in a much higher yield with higher concentrations of important compounds such as phenolics [141]. The fatty acid composition of cold-pressed macadamia nut oil was oleic acid (50.7–63.6%), palmitoleic acid (9.7–20.9%), palmitic acid (6.8–12.0%), and stearic acid (2.8–3.6%) [141]. The solvent extracted oil had oleic acid (40.6–59.9%), palmitoleic acid (15.0–33.8%), palmitic acid (8.4–12.1%), and stearic acid (1.5–5.2%), while the supercritical CO_2 extracted oil had oleic acid (55.6–58.6%), palmitoleic acid (15.3–16.0%), palmitic acid (1.9–11.8%), and stearic acid (4.2–5.5%) [141]. The major volatile compound from *Macadamia integrifolia* Maiden & Betche nut from Cuba was limonene (15.7 mg/kg) among other compounds (0.01–1.5 mg/kg) [142].

22. Marula Oil

Marula (*Sclerocarya birrea* Hochst., Anacardiaceae) trees are native to southern Africa but have been introduced to several other countries including Australia, India, and Israel [143,144]. The only sample preparation necessary for marula oil extraction is the grinding of the seeds into a powder [145]. Cold-pressed extraction is the preferred method of marula oil extraction as the oxidative stability of the oil is maintained [146]. Aqueous extraction is also a common method of extraction that does not utilize harsh solvents, pressures, or temperatures which could diminish the quality of the oil. Solvent extraction using hexane as the solvent is typically used to extract marula oil on an industrial scale due to the high oil extraction yields which leaves behind roughly only 0.5% of the oil in the cake or meal [146]. Oleic acid is the major fatty acid in marula oil, accounting for 70–78% [144,145,147]. The total tocopherols and sterols were 13.7 mg/100 g and 286.6 mg/100 g, respectively [135,136,138]. The main volatiles reported from the fruit pulp were β-caryophyllene (91.3%) and α-humulene (8.3%), while the intact fruit had heptadecene (16.1%), benzyl 4-methylpentanoate (8.8%), (*Z*)-3-decen-1-ol (8.4%), benzyl butyrate (6.7%), (*Z*)-13-octadecenal (6.2%), and cyclopentadecane (5.7%) [148].

23. Moringa Oil

Moringa (*Moringa oleifera* Lam.) trees are cultivated all over the world but originated in Africa and Asia [146,149]. Moringa trees are most easily grown in dry tropical areas such as the northwestern regions of India, which is why cultivation of the tree is so prevalent and economically valuable there. On an industrial scale, solvent extraction is the traditional method of extraction of moringa oil as many of the important lipids are recovered. The solvent typically used in this extraction is either hexane or petroleum ether. Mechanical methods, including cold-pressing, are standard as well but are typically not used on an industrial-scale as the yield is much lower than through solvent extraction [149]. The fatty acid composition of moringa seed oil was oleic acid (73.4%), palmitic acid (6.1%), behenic acid (5.7%), and stearic acid (5.4%) [150].

24. Neem Seed Oil

Neem (*Azadirachta indica* A. Juss.) trees are indigenous to the Karnataka forests of southern India and the island forests of Myanmar. However, neem trees grow in nearly 80 countries around the world [151]. Neem oil is most commonly extracted by mechanical methods which result in high yields but is typically not pure and may require a refinement process to remove undesirable metals and compounds. Supercritical fluid extraction results in an oil high in purity but very expensive to produce [152]. Solvent extraction using a Soxhlet apparatus is another common method of extraction that results in high oil yields and includes very few undesirable metals and compounds [153]. The average fatty acid composition of neem oil is oleic acid (25–54%), palmitic acid (16–33%), stearic acid (9–24%), and linoleic acid (6–16%) [154]. γ-Tocopherol is the main tocopherol in neem seed oil accounting for 68.9% [155]. The main volatile organic compounds from the hydrodistilled oil were 3,5-diethyl-1,2,4-trithiolane (57.8%), 1-hexadecanol (5.7%), and (*E*)-15-heptadecenal (5.1%) [156].

25. Olive Oil

Domestication of the olive tree (*Olea europaea* L.) is believed to have begun in the Near-East, though in modern times, over 90% of the world's olive production takes place in Mediterranean countries [157,158]. The origin of the olive tree has been debated, but it is believed to have originated in the Mediterranean basin or the Middle East [157]. Olive trees are indigenous to Italy, Greece, Palestine, Syria, and many other surrounding countries [159]. The processing and extraction of olive oil has been traditionally carried out via mechanical methods which included crushing, malaxation, and centrifugation [160]. A reason that mechanical methods are still commonly used even in modern times is the lack of need for further refinement, as olive oil is safe for consumption directly after mechanical extraction [161]. Olive oil extractions on an industrial scale have, in recent years, been adopting microwave, pulsed electric field, and ultrasound assisted olive oil extraction to increase the yield and quality of the extracted oil [160]. The sterol content of extra virgin olive oil was 319 mg/100 g [37]. The main fatty acids in virgin olive oil were oleic acid (78.7%), palmitic acid (8.7%), and linoleic acid (8.3%) [162]. (*E*)-2-hexenal (23.2–27.7%), (*E*,*E*)-α-farnesene (10.5–13.2%), and acetic acid (6.4–8.5%) were the major volatile organic compounds [163].

26. Palm Kernel Oil

It is believed that the oil palm, or *Elaeis guineensis* Jacq., originated in Africa, though some have proposed the origin to be in South America [164]. The most common methods of palm kernel oil extraction, at least in one of the largest palm kernel oil producers in the world, Malaysia, include mechanical methods, which utilize a screw press, direct solvent extraction, and a combination of both methods in which mechanical pressing is followed by solvent extraction [165]. With the dangers of solvent extraction becoming more evident, newer methods, such as the supercritical CO_2 extraction method, have become a more common alternative extraction method due to the use of a solvent that is environmentally friendly [165]. Solvent extraction is typically used to extract palm kernel oil on an industrial level as it requires very expensive equipment but results in very high oil yields [7]. The use of hexane as the solvent has made this method less desirable in recent years as hexane has been labeled a hazardous air pollutant by the United States Environmental Protection Agency, or EPA [7]. The use of supercritical fluids as solvents resolves this issue and greatly reduces harm to the environment [165]. Myristic acid (72.3%) and palmitic acid (25.8%) are the major fatty acids in palm kernel oil [166].

27. Passionfruit Seed Oil

Passionfruit (*Passiflora* spp.) is indigenous to American tropical regions such as Brazil, Paraguay, and northern Argentina along with surrounding countries [167]. Passionfruit is commercially produced in a variety of tropical and sub-tropical regions, such as Australia, Hawaii, South Africa, and Brazil [168]. The main fatty acids in passion fruit seed oil were linoleic acid (73.1%), oleic acid (13.8%), palmitic acid (9.7%), and stearic acid (2.6%) [169]. The tocopherol content of passion fruit seed oil was 465–499 ppm [170]. The major volatiles identified in passion fruit seed oil from Brazil were linalool (25.8%), *n*-octyl acetate (12.5%), ethyl caproate (9.2%), β-ocimene (9.0%), 2-heptanone (5.6%), α-terpineol (4.8%), and benzene acetaldehyde (3.7%) [171].

28. Pomegranate Seed Oil

Pomegranate (*Punica granatum* L.) trees are believed to have originated in Iran or the Near-East. In modern times, pomegranate trees have been distributed and cultivated all over the world and are especially prevalent throughout Eurasia [172]. The pomegranate juice industry provides the left-over seeds to be used in pomegranate oil extraction. These seeds are first cleaned of any other parts of the pomegranate until only the seeds remain. The seeds are then dried and powdered before being used in the extraction of pomegranate oil [173]. Traditionally, extraction methods of pomegranate seed oil include Soxhlet extraction, distillation, cold pressing, hot pressing, and maceration. However, some of these conventional methods degrade the bioactive compounds and result in an oil of lesser quality [173]. Multiple methods of pomegranate seed oil extraction were compared, and it was found that solvent extraction utilizing a Soxhlet apparatus produced the highest yield when compared to extraction by normal stirring, microwave irradiation, ultrasonic irradiation, and supercritical fluid [174]. Stirring had the lowest pomegranate oil yield. It was found that the differences in fatty acid composition were negligible between the compared methods [174]. Production of pomegranate oil on an industrial scale is greatly limited by the waste necessary to extract the oil, and it results in large amounts of waste which has a risk of becoming an environmental hazard [173]. Pomegranate seed oil is a rich source of punicic acid (73.7–80.7%) [175,176]. Ethyl valerate (8.9–16.1%), 2-methylbutyl formate (10.1–17.5%), 2-methylbutyl acetate (3.3–7.8%), hexanal (1.9–7.9%), 2-methyl-1-butanal (1.1–7.2%), pentanal (2.4–5.6%), 3-methyl-1-butanal (0.2–5.4%), butyraldehyde (1.4–9.5%), and 2-butanone (0.2–4.8%) were reported as the major volatile organic compounds [177].

29. Evening Primrose Oil

Evening primrose (*Oenothera* spp.), family Onagraceae, has the highest species diversity in the western United States and Mexico and is believed to have originated there [178,179]. Temperate and subtropical climates are ideal climates for the growth of evening primrose [178,179]. Prior to extraction, the seeds are dried and made into a powder using a grinder [180]. Solvent extraction using *n*-hexane as the solvent is recommended for the extraction of evening primrose oil which results in very minimal changes to its bioactive compounds and in many cases will not require further refinement. Cold press extraction also results in an oil with minimal changes to its bioactive compounds [180]. Linoleic acid dominates the fatty acid content of evening primrose seed oil with 73.9% followed by linolenic acid (9.2%), oleic acid (6.9%), palmitic acid (6.3%), and stearic acid (1.9%) [181] Total sterols and tocopherols of evening primrose seed oil were 9149.2 and 186.3 mg/kg, respectively [182]. The main volatile organic compounds extracted by HS-SPME from primrose seed oil were hexanoic acid (1.3–17.9 mg/kg), (*E*)-2-octenal (1.2–5.9 mg/kg), 1-butanol (3.0–5.4 mg/kg), (*E*)-2-nonenal (0.1–3.6 mg/kg), octanal (1.4–3.4 mg/kg), (*Z*)-9,17-octadecadienal (1.9–3.0 mg/kg), heptanoic acid (0.1–6.6 mg/kg), docosyl docosanoate (0.4–4.6 mg/kg), methyl (*Z*,*Z*)-9,12-octadecadienoate (0.1–6.6 mg/kg), and 5-methyltetradecane (1.9–5.1 mg/kg) [183].

30. Pumpkin Oil

Pumpkins (*Cucurbita maxima* Duchesne) are native to Central and South America but have been domesticated and grown throughout the world [184]. Native Americans were the first to cultivate pumpkins, but in the 1800s, Europe also began cultivation, first in Styria and later in countries surrounding Austria. The United States is the world's largest producer of pumpkins, but other countries, including China, India, and Mexico, are large producers of pumpkins as well [184]. Solvent extraction using a Soxhlet apparatus is a common method of extraction, even on an industrial scale [185]. However, solvent extraction can alter the chemical composition and bioactive compounds due to the use of heat and possibly harsh solvents. Mechanical extraction methods such as cold-press extraction and extraction by mechanical shaking better preserve the chemical composition of pumpkin seed oil but suffer from lower yields [185]. The fatty acid composition of pumpkin seed oils was linoleic acid (44.3–53.2%), oleic acid (28.9–42.6%), palmitic acid (9.1–13.4%), and stearic acid (5.1–5.4%) [186,187]. The sterol and tocopherol contents of pumpkin seed oil were 127.9 and 418.7 mg/100 g, respectively [188]. The major volatiles identified from the seed were heneicosane (26.1%), [2,2,4-trimethyl-3-(2-methylpropanoyloxy)pentyl] 2-methylpropanoate (20.7%), 5,6-dihydro 2,4,6-trimethyl-4*H*-1,3,5-dithiazine (11.1%), eicosane (9.0%), 5-butylhexadecane (4.0%), and 1,8-cineole (2.9%) [189].

31. Raspberry Seed Oil

Raspberries (*Rubus idaeus* L., *R. strigosus* Michx.) are indigenous to the northern temperate zone [109]. Raspberry seed oil can be extracted through a variety of different solvent and mechanical methods [190]. Solvent extraction utilizing a Soxhlet apparatus results in very high yields with no significant deviations in the chemical compositions and bioactive compounds [190]. However, mechanical methods such as cold-press extraction and supercritical fluid extraction would be preferred on an industrial scale as there are fewer hazards and risks to the environment. These ecologically friendly methods, however, do not result in as high yields as solvent extraction. It should also be noted that solvent extraction typically requires more energy than mechanical methods such as cold-press extraction and supercritical fluid extraction [190]. Crude raspberry seed oil had linoleic acid (54.5%), linolenic acid (29.1%), oleic acid (12.0%), and palmitic acid (2.7%) as the main fatty acids [191]. The volatile organic compounds from raspberry seed oil obtained by sonification were (*E*,*E*)-3,5-heptatriene (2.2%), 1,6-heptadien-4-ol (0.7%), 3-methyl-1 butanol (2.5%), 3-methyl-1-butanyl acetate (1.1%), 2-methyl-1-propanol (1.9%), (*E*)-2-hexenal (1.0%), 3-methyl-3-buten-1-ol (1.3%), (*Z*)-3-hexen-1-yl acetate (1.0%), acetic acid (2.2%), methyl acetate (1.1%), benzene (1.3%), ethanol (1.6%), ethyl acetate (8.8%), hexanal (2.5%), 2,2-dimethylpropanal (3.1%), propylene oxide (1.2%), and *p*-xylene (1.2%) [109].

32. Rosehip Oil

Rosehip (*Rosa canina* L.) grows naturally in Europe, Northwest Africa, and Asia [192]. The exact place of origin of Rosehip is unknown, but it is believed that one of the origin points is in Anatolia, Turkey [192,193]. Rosehip oil is first processed by drying the fruits and separating the seeds, skins, and flesh. The parts of the dried fruit are crushed and turned into a powder, which is later used in the extraction of rosehip oil [194]. Solvent extraction is conventionally used in the extraction of rosehip oil and results in high oil yields, which are lower in quality and require an extensive refining process that removes important bioactive compounds from the oil [195]. Due to the oil content in the seeds, mechanical methods are not preferred; however, supercritical fluid extraction has been shown to be a mechanical method that preserves the bioactive compounds and results in a higher-quality oil [195]. The main fatty acid species in rosehip seed oil were linoleic acid (47.0–54.0%), linolenic acid (19.4–40.2%), oleic acid (19.5%), palmitic acid (3.4–3.7%), stearic acid (1.7%) [196,197]. The major volatile components from *R. canina* fruit were butanoic acid (25.7%), 1,2-propanediol (22.5%), α-humulene (8.3%), naphthalene (6.6%), phenylethyl alcohol (5.9%), 2,4-bis(1,1-dimethylethyl)phenol (5.9%), ionone (3.7%), formic acid (3.1%), 3-methyl-1-butanol (2.2%), acetic acid (1.3%), 2-methyl-1-propanol (1.1%), 2-furanmethanol (3.0%), and α,α,4-trimethyl-3-cyclohexene-1-methanol (1.0%); while *R. dumalis* fruit had 3-methyl-1-butanol (14.2%), 1-penten-3-ol (10.4%), 2-methyl-1-propanol (8.7%), 2-ethyl-1-hexanol (6.4%), 1-butanol (5.6%), 2,4-bis(1,1-dimethylethyl)phenol (4.3%), 2-nonen-1-ol (4.1%), 2(3*H*)-furanone (4.0%), 3-methylpentanoic acid (3.8%), 3,7-dimethyl-1,6-octadien-3-ol (3.8%), isoamyl isovalerate (3.8%), acetic acid (3.4%), 2-furanmethanol (3.3%), α,α,4-trimethyl-3-cyclohexene-1-methanol (2.4%), 1,2-propanediol (2.3%), phenol (2.0%), 4-hexen-1-ol (2.0%), dodecanol (2.0%), decanal (1.9%), 3-methylpentanoic acid (1.7%), butyl hexanoate (1.6%), hexyl hexanoate(1.6%), butanoic acid (1.4%), phenylethyl alcohol (1.3%), and benzaldehyde (1.2%) [198]. *R. pimpinellifolia* fruit contained naphthalene (26.7%), acetic acid (13.4%), nonanoic acid (9.0%), sinapic acid (6.7%), 2-nonen-1-ol (5.7%), benzoic acid (3.7%), 1-hydroxy-2-propanone (3.5%), formic acid (3.2%), furfural (3.1%), 2,4-dimethoxycinnamic acid (2.8%), acetone (2.8%), hexanoic acid (2.0%), 2-furanmethanol (1.9%), phenol (1.9%), ionone (1.9%), 2,4-bis(1,1-dimethylethyl)phenol (1.8%), 3-methylbutanoic acid (1.7%), dodecanoic acid (1.7%), *n*-decanoic acid (1.4%), octanoic acid (1.3%), and 1,2-benzenedicarboxylic acid (1.1%) as the main volatiles [198]. The volatiles from *R. villosa* fruit were ethanol (28.7%), 3-methyl-1-butanol (11.6%), acetic acid (7.9%), 1-pentanol (7.6%), α-humulene (6.1%), naphthalene (6.1%), 1-hydroxy-2-propanone (4.5%), phenol (3.8%), 2-furanmethanol (3.7%), formic acid (3.5%), α,α,4-trimethyl-3-cyclohexene-1-methanol (2.9%), furfural (2.8%), 1,2-benzenedicarboxylic acid (2.5%), 2(3*H*)-furanone (2.0%), and 3-methylbutanoic acid (1.4%) [198].

33. Sacha Inchi Oil

Sacha Inchi (*Plukenetia volubilis* L.) originates from the Amazonian regions of Brazil and has a growth distribution throughout South America and even some islands in the Caribbean [199,200]. The fatty acid composition of Sacha inchi crude oil was linolenic acid (47.0–50.8%), linoleic acid (33.4–36.0%), oleic acid (9.0–9.1%), palmitic acid (4.0–4.4%), and stearic acid (2.4–3.0%) [201,202].

34. Safflower Oil

The exact origins of the safflower (*Carthamus tinctorius* L., Asteraceae) plant are unknown. However, it is believed that it was first domesticated in the Middle East over 4000 years ago [203]. In modern times, China, India, Mexico, Turkey, and the United States are some of the largest producers of safflower in the world [204]. The most common methods of safflower oil extraction on an industrial level are either solvent extraction or expeller pressing extraction. However, both methods have disadvantages as further refining is necessary for solvent extraction, and expeller pressing thermally degrades important bioactive components of the oil. Both high-yield industrial extraction methods result in low-quality oils [204]. Supercritical CO_2 extraction is a method of extraction that overcomes the issue of bioactive component degradation. This method also requires no further refinement of the oil for human consumption [204]. The method is also much more environmentally friendly as CO_2 is only very mildly toxic, is not flammable, and is very inexpensive [205]. The fatty acid composition of safflower oil was linoleic acid (44.3–83.7%), oleic acid (7.5–42.6%), palmitic acid (4.0–13.4%), and stearic acid (1.7–5.4%) [206]. The major volatile compounds identified by HS-SPME-GC-MS from safflower seed oil were *n*-hexanol (4.9–29.9%), *n*-hexanal (10.6–23.2%), 2-octene (0–15.6%), acetic acid (0.8–10.2%), (*E*)-2-heptenal (2.4–8.8%), 1-octen-3-ol (2.2–4.3%), caproic acid (1.0–7.9%), methacrylonitrile (1.2–7.3%), α-pinene (1.5–5.2%), 2-*n*-pentylfuran (1.4–4.7%), 1-pentanol (1.4–3.5%), *p*-cymene (0.8–3.2%), 2-octenal (1.0–2.7%), benzaldehyde (2.2–2.4%), isovaleric acid (1.6–2.1%), limonene (1.4–2.1%), 3-octene-2-one (0.8–1.7%), isoamyl alcohol (0.1–1.5%), nonanal (0.5–1.5%), sabenene (0.6–1.3%), 1-hexadecene (1.0–1.3%), and (*E*)-2-hexenal (0.3–1.2%) [207].

35. Sea Buckthorn Oil

Sea buckthorn trees (*Hippophae rhamnoides* L.) grow in the temperate zones of Europe and Asia where they are indigenous [208]. Sea buckthorn oil can come from either seeds or fruit pulp, in which the seeds have a slightly higher yield than the fruit pulp [209]. The chemical composition of sea buckthorn oil changes significantly depending on what part of the fruit was used in extraction [209]. Cold-press extraction, solvent extraction using hexane, and supercritical CO_2 extraction methods of sea buckthorn seed oil were compared, and it was found that supercritical CO_2 extraction resulted in the oil with the highest sterol percentage [210]. The fatty acid composition of sea buckthorn oil was palmitic acid (49.4%), palmitoleic acid (28.0%), oleic acid (11.7%), linoleic acid (4.1%), *cis*-vaccenic acid (4.5%), and α-linolenic acid (4.5%) [211,212]. The total sterols, carotenoids, and tocopherols were 748.1, 22.2, and 421.7 mg/100 g, respectively [211,212].

36. Sesame Seed Oil

Sesame (*Sesamum indicum* L.) originated from East Africa and India, and it is believed that it was first cultivated in South Asia over 5000 years ago [213]. Some sources, however, refute this claim though and believe that sesame cultivation began first in Africa [214]. Hot water flotation is a traditional method of sesame oil extraction originating in Uganda and Sudan. It involves the grinding of sesame seeds and extraction by adding boiling water to the ground seeds which suspends the oil once the mixture has cooled [215]. This traditional method of oil extraction has a yield of around 41%. More advanced methods of extraction such as the bridge press method, result in yields over 70% [215]. The main fatty acids in virgin sesame oil are linoleic acid (41.8%), oleic acid (40.4%), palmitic acid (10.8%), and stearic acid (5.5%) [216]. The volatile compounds reported from sesame seed oil were hexanal (15.8%), β-ocimene (11.9%), 1-hexanol (9.5%), ethanol (8.2%), α-pinene (5.8%), acetic acid (5.1%), 2-pentylfuran (4.9%), 1-pentanol (3.9%), ethylbenzene (3.6%), 2-methylbutanal (3.5%), butyrolactone (3.5%), 3-methylbutanal (3.2%), 2,3-butanediol (2.4%), decane (2.1%), and 1,2,4-trimethyl benzene (2.0%) [217].

37. Shea Butter

Shea trees (*Vitellaria paradoxa* C.F.Gaertn., Sapotaceae) are naturally found in a 6000 km by 500 km belt ranging between Senegal and Uganda in Africa [218]. Traditional processing methods of shea butter began with the harvest of dropped nuts from shea trees [219]. The nuts are washed, dried, and cracked to collect the kernel, which will be milled, roasted, and then used in the laborious extraction process of shea butter [219]. The fatty acids in crude shea butter are stearic acid (43.5–45.8%), oleic acid (42.5–45.8%), linoleic acid (5.9–6.1%), and palmitic acid (3.2–4.1%) [220,221]. The tocopherol content of crude shea butter was 10.1 mg/100 g, while the phytosterol content was 20.8 mg/g [221].

38. Soybean Oil

It is believed that the origin of soybean (*Glycine max* (L.) Merr.) is in either the northeastern or southern regions of China. Its domestication began in East Asia somewhere between 6000 and 9000 years ago [222]. Mechanical methods of extraction are the most common method of soybean oil extraction even though it results in a lower yield [223]. This method allows for the later use of the left-over soybean cake as it has not been contaminated with solvents that are harsh for the environment. The solvent extraction method has a very high extraction efficiency of 98% but is a less environmentally friendly extraction method. The industrial level extraction of soybean oil usually utilizes combinations of mechanical and chemical methods to result in very high oil yields [223]. The fatty acid composition of soybean oil was linoleic acid (53.2%), oleic acid (23.1%), palmitic acid (11.4%), linolenic acid (7.5%), and stearic acid (4.1%) [223]. The total sterol and tocopherol contents were 397 and 94.9 mg/100 g, respectively [223].

39. Sunflower Oil

Domesticated sunflower (*Helianthus annuus* L.) is believed to have originated somewhere in Mexico [224]. Most industrial extractions of sunflower oil involve mechanical extraction by a hydraulic or expeller press followed by solvent extraction to extract a very high yield from the seeds [225]. Continuous methods of mechanical extraction, such as twin screw-press extraction, are preferable on an industrial scale as the extraction of oil can be made less time consuming [225]. The fatty acid composition of sunflower oil was linoleic acid (48.3–74.0%), oleic acid (14.0–39.4%), palmitic acid (5.0–7.6%), and stearic acid (2.3–4.0%) [226]. The total phytosterol content of sunflower oil was 125–765 mg/100 g, while the tocopherol content was 176.9–1872 mg/kg [226]. The main volatile compounds from sunflower seed oil were α-pinene (59.6%), α-thujene (4.9%), γ-terpinene (4.2%), *p*-cymene (3.4%), β-pinene (3.2%), α-terpinene (3.0%), limonene (2.7%), camphene (2.6%), α-terpinolene (2.2%), sabinene (2.2%), calarene (1.5%), verbenene (1.2%), and α-phellandrene (1.0%) [217].

40. Tamanu Oil

Tamanu (*Calophyllum inophyllum* L.) is native to tropical parts of Asia and is distributed not only across Asia but also Polynesia, Micronesia, and Melanesia [227,228]. Two high oil yield extraction methods, supercritical CO_2 and Soxhlet extraction, were compared and it was found that supercritical CO_2 resulted in a higher percentage of fatty acids than the Soxhlet extraction method [229]. The oil extracted through supercritical CO_2 extraction was found to have more antibacterial properties than the oil extracted through Soxhlet extraction [229]. Tamanu oils contained oleic acid (37.7–38.9%), linoleic acid (31.8–33.8%), palmitic acid (12.9–13.5%), and stearic acid (12.4–14.0%) as the major fatty acids [229].

41. Volatile Composition

Table 1 summarizes the volatile composition of carrier oils. Interestingly, no information was found on the VOCs of babassu, baobab, chia, hazelnut, jojoba, kukui nut, palm kernel, sacha inchi, sea buckthorn berry, shea butter, sunflower, and tamanu.

Table 1. Volatile composition of carrier oils.

Carrier Oil	VOC Extraction Method	Origin	Volatile Organic Compounds	Ref.
Bitter Almond Oil (Cold pressed)	Purge and Trap Extraction	Iran	hexanal, nonanal, benzaldehyde, (*E*)-decenal, (*E*,*E*)-2,4-nonadienal, 2-phenyl-2-propanol, benzyl alcohol, octadecanol, hexanoic acid, heptanoic acid, octanoic acid, benzoic acid, 2-pentylfuran, α-pinene, β-pinene, sabinene, δ-3-carene, limonene, γ-terpinene, *p*-cymene, 4-terpineol	[18]
Sweet Almond Oil (Cold pressed)	Purge and Trap Extraction	Iran	hexanal, octanal, nonanal, furfural, benzaldehyde, (*E*,*E*)-nonadienal, 2-undecenal, (*E*,*E*)-2,4-decadienal, 3-pentel-2-ol, octanol, 2-phenyl-2-propanol, benzyl alcohol, hexanoic acid, octanoic acid, 2-octanone, 4-nonanone, methylpyrazine, 2,5-dimethylpyrazine, 2,6-dimethylpyrazine, methylethylpyrazine, 2-ethylpyrazine, δ-3-carene, limonene, *p*-cymene	[18]
Ferragnes Almonds (Soxhlet Solvent Extraction Using *n*-Hexane)	Solid Phase Microextraction	France	butanal, toluene, butyl acetate, 2-methyl-1-propanol, 4-methyl-6-hepten-3-one, ethylbenzene, 2,5-dimethyl-3-hexanone, butanol, 3-heptanone, 3-methylbutanol, 2-hexanol, 4-octanone, 3-octanone, butyl valerate, pinacol, 1-hexanol, 2-nonanone, 2-methylpentanal, isobutyric acid, valeric acid, 2-phenyl-2-propanol, γ-decalactone, γ-undecalactone, diethyl phthalate	[230]
Ferraduel Almonds (Soxhlet Solvent Extraction Using *n*-Hexane)	Solid Phase Microextraction	France	butanal, 3-methyl-2-pentanone, toluene, butyl acetate, 2-methyl-1-propanol, isoamyl acetate, ethylbenzene, 2.5-dimethyl-3-hexanone, butyl isobutyrate, butanol, 3-heptanone, butyl butyrate, 4-octanone, 3-octanone, *m*-cymene, butyl valerate, 2-nonanone, 2-methylpentanal, isobutyric acid, valeric acid, 2-phenyl-2-propanol, γ-undecalactone, diethyl phthalate	[230]
Marta Almonds (Soxhlet Solvent Extraction Using *n*-Hexane)	Solid Phase Microextraction	France	3-methyl-2-pentanone, toluene, butyl acetate, hexanal, isoamyl acetate, ethylbenzene, butanol, limonene, 2-hexanol, 4-octanone, 2-heptenal, pinacol, 2-nonanone, 2-methylpentanal, benzaldehyde, γ-butyrolactone, 2-decenal, phenylacetaldehyde, 2-phenyl-2-propanol, γ-decalactone, diethyl phthalate	[230]
Lauranne Almonds (Soxhlet Solvent Extraction Using *n*-Hexane)	Solid Phase Microextraction	France	butanal, toluene, butyl acetate, 2-methyl-1-propanol, ethylbenzene, butyl isobutyrate, butanol, 3-heptanone, 3-methyl-butanol, butyl butyrate, butyl butyrate, 4-octanone, *m*-cymene, pinacol, 2-nonanone, 2-methylpentanal, benzaldehyde, isobutyric acid, phenylacetaldehyde, 2-phenyl-2-propanol, γ-undecalactone	[230]
Texas Almonds (Soxhlet Solvent Extraction Using *n*-Hexane)	Solid Phase Microextraction	United States	2-methylbutanal, ethanol, α-pinene, toluene, butyl acetate, hexanal, 2-methyl-1-propanol, 4-methyl-6-hepten-3-one, 2.5-dimethyl-3-hexanone, butanol, 2-heptanone, 3-methyl-butanol, 2-hexanol, 4-octanone, 3-octanone, *m*-cymene, pinacol, 1-hexanol, 2-nonanone, 2-methylpentanal, benzaldehyde, 2-decenal, valeric acid, 2-phenyl-2-propanol, γ-undecalactone	[230]

Table 1. *Cont.*

Carrier Oil	VOC Extraction Method	Origin	Volatile Organic Compounds	Ref.
Nonpareil Almonds (Soxhlet Solvent Extraction Using *n*-Hexane)	Solid Phase Microextraction	United States	2-methylbutanal, 3-methylbutanal, ethanol, α-pinene, toluene, butyl acetate, hexanal, 2,5-dimethyl-3-hexanone, butanol, limonene, 4-octanone, 2-heptenal, pinacol, 2-nonanone, 2-methylpentanal, benzaldehyde, 2-decenal, phenylacetaldehyde, 2-phenyl-2-propanol, diethyl phthalate	[230]
Guara Almonds (Soxhlet Solvent Extraction Using *n*-Hexane)	Solid Phase Microextraction	Spain	butanal, α-pinene, toluene, butyl acetate, hexanal, ethylbenzene, butanol, 3-heptanone, limonene, 2-hexanol, 4-octanone, 3-octanone, 2-heptenal, pinacol, 2-nonanone, 2-methylpentanal, benzaldehyde, 2-decenal, phenylacetaldehyde, 2-phenyl-2-propanol, γ-decalactone	[230]
Yaltinskii Almonds (Soxhlet Solvent Extraction Using *n*-Hexane)	Solid Phase Microextraction	Russia	butanal, 3-methyl-2-pentanone, α-pinene, toluene, butyl acetate, 4-methyl-6-hepten-3-one, ethylbenzene, butanol, 2-heptanone, 3-methyl-butanol, 2-hexanol, 4-octanone, *m*-cymene, butyl valerate, pinacol, 1-hexanol, 2-methylpentanal, benzaldehyde, 2-decenal, valeric acid, 2-phenyl-2-propanol, γ-undecalactone	[230]
Nurlu Almonds (Soxhlet Solvent Extraction Using *n*-Hexane)	Solid Phase Microextraction	Turkey	butanal, 3-methylbutanal, ethanol, α-pinene, toluene, butyl acetate, 2-methyl-1-propanol, ethylbenzene, 2.5-dimethyl-3-hexanone, butyl isobutyrate, butanol, 2-heptanone, limonene, 2-hexanol, 4-octanone, 2-heptenal, pinacol, 2-nonanone, 2-methylpentanal, γ-butyrolactone, valeric acid, 2-phenyl-2-propanol, γ-decalactone, diethyl phthalate	[230]
Acıbadem Almonds (Soxhlet Solvent Extraction Using *n*-Hexane)	Solid Phase Microextraction	Turkey	butanal, 2-methylbutanal, 3-methylbutanal, toluene, butyl acetate, hexanal, 4-methyl-6-hepten-3-one, ethylbenzene, 2,5-dimethyl-3-hexanone, butanol, 3-heptanone, 2-hexanol, 4-octanone, 2-heptenal, pinacol, 2-nonanone, 2-methylpentanal, benzaldehyde, 2-decenal, valeric acid, 2-phenyl-2-propanol, γ-decalactone, diethyl phthalate	[230]
Apricot Fruit	Solid Phase Microextraction	Turkey	2-methylbutanal, 3-methylbutanal, hexanal, 4-pentenal, heptanal, (*E*)-2-hexenal, nonanal, 2-octenal, benzaldehyde, 2,3-butandione, 3-hydroxy-2-butanone, 6-methyl-5-hepten-2-one, β-ionone, γ-decalactone, ethyl acetate, methyl propaonate, methyl butanoate, ethyl butanoate, butyl acetate, butyl butanoate, hexyl acetate, (*Z*)-3-hexenylacetate, (*E*)-2-hexenylacetate, ethanol, 1-butanol, 1-pentanol, 1-hexanol, 3-hexanol, 2-hexen-1-ol, linalool, α-pinene, sabinene, β-myrcene, limonene, β-phellandrene, 2-methylpropanoic acid, 2-methylbutanoic acid, decane, toluene, 2-methyltetrahydrofuran, *tert*-butyl-benzene	[231]
Apricot Kernel Oil	Unknown	Korea	benzaldehyde, mandelonitrile, benzoic acid	[26]
Apricot Kernel Oil (Hydrodistillation)	Head Space Solid Phase Microextraction	Greece	toluene, 2,3-butanediol, ethylbenzene, 2-methyl-propanal, 1,3-dimethyl-benzene, nonane, benzaldehyde, 1,2,4-trimethyl-benzene, 1,2,3-trimethyl-benzene, decane, benzyl alcohol, butyl-cyclohexane, 1,2-diethylbenzene, 1-methyl-3-propylbenzene, 1-methyl-2-propylbenzene, 1-ethyl-3,5-dimethylbenzene, 2-ethyl-1,3-dimethylbenzene, *o*-cymene, 2-ethyl-1,4-dimethylbenzene, decahydro-2-methylnaphthalene, 1,2,3,5-tetramethylbenzene, 1,2,4,5-tetramethylbenzene, undecane, 2,3-dihydro-4-methyl-1*H*-indene, 1-phenyl-1-butene, 1,2,3,4-tetramethyl-5-methylene-1,3-cyclopentadiene, 1-phenyl-1,2-propanedione, benzyl acetate, azulene, ethyl benzoate, 2,4-diethyl-1-methyl-benzene, 1-methyl-4-(1-methylpropyl)-benzene, 6-methylundecane, 2-methylundecane, benzoin, dodecane, 2,6-dimethyl-undecane, tridecane	[30]
Argan Oil (cold pressed)	Purge and Trap Extraction	Morocco	2-methyl-2-butanol, 3-penten-2-ol, isoamyl alcohol, pentanol, 2-hexanol, 2,3-butanediol, 1,3-butanediol, 1,2-propanediol, benzyl alcohol, phenylethyl alcohol, methyl pyrazine, 2,5-dimethylpyrazine, 2,6-dimethylpyrazine, ethylpyrazine, 2-ethyl-6-methylpyrazine, 2-ethyl-5-methylpyrazine, 2,3,5-trimethylpyrazine, 2,5-dimethyl-3-ethylpyrazine, 2,3-diethyl-5-methylpyrazine, acetic acid, propanoic acid, isobutanoic acid, butanoic acid, 2-methylbutanoic acid, hexanoic acid, furfuryl alcohol, 5-methylfurfuryl alcohol, 1-methyl-1*H*-pyrrole, 2-formylpyrrole, γ-valerolactone, γ-butyrolactone, phenol, *p*-cresol, 2-octanone, nonanal	[36]

Table 1. *Cont.*

Carrier Oil	VOC Extraction Method	Origin	Volatile Organic Compounds	Ref.
Avocado Fruit	Likens-Nickerson Extraction	Cuba	acetaldehyde, ethanol, acetic acid, diacetyl, 3-penten-2-one, pyridine, pentanol, toluene, hexanal, 2-furfural, (*Z*)-3-hexenol, hexanol, methional, α-pinene, (*E*)-2-heptenal, benzaldehyde, β-pinene, 2-pentylfuran, *p*-cymene, limonene, (*Z*)-β-ocimene, cyclohexyl acetate, (*E*)-β-ocimene, γ-terpinene, (*E*)-2-octenal, *p*-methylbenzaldehyde, perillene, (*E*)-2-nonenal, (*Z*)-4-decenal, (*Z*)-7-decenol, decanal, benzothiazole, (*E*)-anethole, (*E*,*Z*)-2,4-decadienal, 10-undecenal, 4-vinylguaiacol, (*E*,*E*)-2,4-decadienal, cyclosativene, α-copaene, β-elemene, (*Z*)-jasmone, β-caryophyllene, *trans*-α-bergamotene, α-humulene, *allo*-aromadendrene, 9-*epi*-β-caryophyllene, germacrene D, bicyclogermacrene, (*E*,*E*)-α-farnesene, δ-cadinene, β-sesquiphellandrene, (*Z*)-nerolidol, caryophyllene oxide, guaiol, tetradecanal, α-cadinol, bulnesol, α-bisabolol, mintsulfide, tetradecanoic acid, (*E*)-β-santalol, (*E*,*E*)-farnesyl acetate, methyl hexadecanoate, hexadecanoic acid	[45]
Avocado Seed Oil (cold pressed)	Solid Phase Microextraction	Turkey	d-limonene, α-cubebene, β-caryophyllene, pulegone, β-curcumene, hexanal, heptanal, octanal, nonanal, (*Z*)-5-tridecene, 2-heptanone, 2-octanone, 2-decanone, durene, isodurene, biphenyl, undecane, dodecane, tridecane	[232]
Black Cumin Seed	DBWAX Column GC-MS	China	β-thujene, β-pinene, α-terpinolene, d-limonene, γ-terpinene, *o*-cymene, *cis*-4-methoxy thujane, *p*-mentha-1,5,8-triene, *p*-cymenene, acetic acid, (*E*)-longipinene, ylangene, *trans*-2-caren-4-ol, 1,3,4-trimethyl-3-cyclohexene-1-carboxaldehyde, verbenone, longifolene, butanoic acid, estragole, carvone, thymoquinone, anethole, *p*-cymen-8-ol, isolongifolyl acetate, (*Z*)-18-octadec-9-enolide, 9(*E*),11(*E*)-conjugated linoleic acid, nonanoic acid, phenol, 2-methyl-5-(1-methylethyl)phenol, 6-methyl-5-(1-methylethyl)-5-hepten-3-yn-2-ol, *p*-cymene-2,5-diol, (*Z*,*Z*,*Z*)-9,12,15-octadecatrienoic acid, 3,6-dimethylbenzo[b]thiophene	[66]
Black Cumin Seed Extract	Purge and Trap Extraction	Turkey	acetic acid, propanoic acid, isobutanoic acid, butanoic acid, propenoic acid, pentanoic acid, hexanoic acid, (*E*)-3-hexenoic acid, heptanoic acid, octanoic acid, nonanoic acid, hexadecanoic acid, octadecanoic acid, 2-methyl-3-butanol, 3-penten-2-ol, (*Z*)-2-methyl-2-buten-1-ol, furfuryl alcohol, 2-(2-ethoxyethoxy)ethanol, benzyl alcohol, phenethyl alcohol, guaiacol, phenol, eugenol, limonene, benzyl acetate, ethyl 4-ethoxybenzoate, acetoin, hydroxyacetone, furfural, butyrolactone, *m*-xylene, styrene	[18]
Black Cumin Oil (cold pressed)	Solid Phase Microextraction	Turkey	hexanal, α-thujene, α-pinene, sabinene, β-pinene, 2-heptenal, α-terpinene, limonene, *p*-cymene, γ-terpinene, (*E*)-2-octenal, nonanal, 4-terpineol, thymoquinone, (*E*,*E*)-2,4-decadienal, α-longipinene, isolongifolene	[233]
Brazil Nut	GCO with both Carbowax 20M and SE30 Columns	Brazil	hexanal, heptanal, 2,4-nonadienal, 2,4-decadienal, ethanol, 1-butanol, 1-pentanol, 2-methyl-2-butanol, 1-hexanol, 1-octanol, 2-nonanol, phenol, cresol, 2-heptanone, 2-nonanone, 2-decanone, 2-undecanone, 2-dodecanone, benzaldehyde, *n*-nonane, *n*-decane, *n*-undecane, *n*-dodecane, *n*-tridecane, toluene, ethylbenzene, styrene, *n*-butylbenzene, 1,2,3-trimethylbenzene, 1,2,4-trimethylbenzenene, 1,3,5- trimethylbenzenene, naphthalene, 2-methylnaphthalene, limonene, ethyl acetate, benzofuran, methylbenzofuran, cyanobenzene, chloroform	[75]
Brazil Nut Oil (cold pressed)	Head Space Solid Phase Microextraction	Brazil	hexanal, (*E*)-2-heptenal, (*E*)-2-octenal, nonanal, 3-octen-2-one, 2-nonanone, 1-heptanol, 1-octen-3-ol	[234]

Table 1. *Cont.*

Carrier Oil	VOC Extraction Method	Origin	Volatile Organic Compounds	Ref.
Chia Seed Oil	Head Space Solid Phase Microextraction	The United States	hexanal, 2-pentenal, (2*Z*)-heptanal, nonanal, 2-octanal, (2*E*,4*E*)-heptadienal, 3-octen-2-one, (3*E*,5*E*)- octadien-2-one, 1-penten-3-ol, 2-methyl-3-pentanol, 1-hexanol, 1-octen-3-ol, propanoic acid, butanoic acid, hexanoic acid, octanoic acid, nonanoic acid, 2-ethylfuran, 2-pentylfuran, α-Pinene, sabinene, β-pinene, *o*-xylene, β-myrcene, limonene, *p*-cymene, phenol	[235]
Coconut Oil (expeller)	Head Space Solid Phase Microextraction	Philippines	acetic acid, hexanal, 2-heptanone, limonene, nonanal, δ-octalactone, δ-decalactone, dodecanoic acid	[104]
Coconut Oil (centrifuge)	Head Space Solid Phase Microextraction	Philippines	hexanal, 2-heptanone, octanoic acid, δ-octalactone, dodecanoic acid	[104]
Coconut Oil (fermentation without heat)	Head Space Solid Phase Microextraction	Philippines	ethyl acetate, acetic acid, hexanal, 2-heptanone, limonene, nonanal, octanoic acid, ethyl octanoate, δ-octalactone, δ-decalactone, dodecanoic acid	[104]
Coconut Oil (fermentation without heat)	Head Space Solid Phase Microextraction	Philippines	acetic acid, 2-pentanone, hexanal, nonanal, octanoic acid, δ-octalactone, dodecanoic acid	[104]
Cranberry Seeds (sonication)	Head Space Solid Phase Microextraction	Poland	1,2-dimethyl cyclopropane, 1,3,5,7-cyclooctatetraene, 1-penten-3-one, (*E*,*E*)-2,4-heptadienal, (*E*)-2-butenal, (*Z*)-2-heptenal, 2-hexenal, (*E*)-2-Penten-1-ol, 2-pentenal, (*E*)-2-pentene, (*Z*)-4-heptenal, acetic acid, ethyl acetate, 2-ethylfuran, furfural, hexanal, hexane, (*S*)-methyloxirane, pentanal, trimethylene oxide	[109]
Grape Seeds		Turkey	ethyl octanoate, ethyl decanoate, ethyl dodecanoate, and hexyl hexadecanoate	[116]
Cabernet Grapeseeds		Turkey	isoamyl acetate, isoamyl alcohol, ethyl heptanoate, hexyl acetate, octanal, nonanal, ethyl octanoate, 1-octen-3-ol, heptyl alcohol, *n*-decanal, nonanol, ethyl laurate, isovaleric acid, valeric acid, phenylethyl acetate, hexanoic acid, phenylethyl alcohol, heptanoic acid, octanoic acid, nonanoic acid	[116]
Gamay Grapeseeds		Turkey	isoamyl acetate, isoamyl alcohol, ethyl heptanoate, hexyl acetate, octanal, 2-nonanone, nonanal, ethyl octanoate, 1-octen-3-ol, heptyl alcohol, *n*-decanal, 2,3-butanediol diacetate, benzaldehyde, nonanol, ethyl laurate, isovaleric acid, valeric acid, phenylethyl acetate, hexanoic acid, phenylethyl alcohol, heptanoic acid, octanoic acid, nonanoic acid, β-caryophyllene, myrcene, valencene, benzyl acetate	[116]
Kalecik Karasi Grapeseeds		Turkey	isoamyl acetate, ethyl heptanoate, hexyl acetate, octanal, nonanal, ethyl octanoate, 1-octen-3-ol, heptyl alcohol, 2,3-butanediol diacetate, benzaldehyde, nonanol, ethyl laurate, isovaleric acid, benzyl acetate, phenylethyl acetate, hexanoic acid, phenylethyl alcohol, heptanoic acid, octanoic acid	[116]
Okuzgozu Grapeseeds		Turkey	isoamyl acetate, ethyl heptanoate, hexyl acetate, octanal, nonanal, ethyl octanoate, 1-octen-3-ol, heptyl alcohol, benzaldehyde, nonanol, ethyl laurate, phenylethyl alcohol, octanoic acid	[116]
Senso Grapeseeds		Turkey	isoamyl acetate, ethyl heptanoate, hexyl acetate, octanal, nonanal, ethyl octanoate, 1-octen-3-ol, heptyl alcohol, *n*-decanal, benzaldehyde, nonanol, ethyl laurate, isovaleric acid, phenyl-ethyl acetate, hexanoic acid, phenyl-ethyl alcohol, octanoic acid	[116]
Magliocco Canino Grape Seed Oil (solvent-assissted extraction)	Purge and Trap Extraction	Italy	3-penten-2-ol, 3-hexanol, 2-hexanol, 1-methyl cyclopentanol, 3-methyl-cyclopentanol, 1-hexanol, 1-octanol, 2-phenyl-2-propanol, phenylethyl alcohol, isoamyl acetate, ethyl octanoate, phenylethyl acetate, ethyl dodecanoate, hexanal, nonanal, 2-nonanone, 4-ethoxybenzoic acid, 2-methyl-2-buten-1-ol, 2-butoxyethanol, 1-octen-3-ol, 2,3-butanediol, benzyl alcohol, 2-phenoxyethanol, ethyl decanoate, (*E*,*E*)-2,4 heptadienal, acetophenone, 2-dodecanone, β-cubebene, germacrene, phenol, hexanoic acid, octanoic acid, nonanoic acid, γ-butyrolactone	[236]

Table 1. *Cont.*

Carrier Oil	VOC Extraction Method	Origin	Volatile Organic Compounds	Ref.
Dimrit Grape Seed Oil (solvent-assissted extraction)	Purge and Trap Extraction	Turkey	3-hexanol, 2-hexanol, 1-hexanol, 1-octen-3-ol, 2-phenyl-2-propanol, benzyl alcohol, phenylethyl alcohol, 2-phenoxyethanol, isoamyl acetate, ethyl octanoate, ethyl dodecanoate, hexanal, (*E*)-2-heptanal, nonanal, (*E*)-2-nonenal, benzene, acetaldehyde, acetophenone, isocumene, phenol, 3,5-xylenol, 2,4-dimethylphenol, carvacrol, 3,4-dimethylphenol, 2,4-di-*tert*-butyl phenol, hexanoic acid, 2-ethylhexanoic acid, octanoic acid, 2-pentylfuran, γ-butyrolactone, dihydroxymaltol, 2-butoxyethanol	[236]
Hazelnut Oil (cold pressed)	Solid Phase Microextraction	Turkey	2-heptenal, nonanal, (*E*,*E*) 2,4-decadienal, (*E*)-2-decenal, (*E*,*Z*)-2,4-decadienal, (*E*)-2-tridecenal, heptanal, hexanal	[233]
Hemp Flowers and Leaves	Dynamic Head Space Collection	Canada, France, Finland	(*Z*)-3-hexen1-yl acetate, α-pinene, β-pinene, β-myrcene, limonene, (*Z*)-β-ocimene, (*Z*)-β-caryophyllene, α-humulene	[128]
Hemp (Hydrodistillation)	Head Space Solid Phase Microextraction	Italy	α-pinene, camphene, β-pinene, myrcene, limonene, 1,8-cineol, (*Z*)-β-ocimene, (*E*)-β-ocimene, γ-terpinene, terpinolene, linalool, β-caryophyllene, (*E*)-β-farnesene, α-humulene, caryophyllene oxide, β-eudesmol, β-bisabolol, α-bisabolol	[237]
Hemp (Supercritical Fluid CO_2) Extract	Head Space Solid Phase Microextraction	Italy	α-pinene, camphene, β-pinene, myrcene, limonene, 1,8-cineol, (*Z*)-β-ocimene, (*E*)-β-ocimene, γ-terpinene, terpinolene, linalool, β-caryophyllene, (*E*)-β-farnesene, α-humulene, caryophyllene oxide, β-eudesmol, β-bisabolol, α-bisabolol	[237]
Macadamia Nut	Likens-Nickerson Extraction	Cuba	hexanal, ethyl butyrate, butyl acetate, 2-furfural, ethylbenzene, *p*-xylene, hexanol, isoamyl acetate, *o*-xylene, 2-heptanone, heptanal, cumene, benzaldehyde, propylbenzene, β-pinene, 6-methy-5-hepten-2-ol, ethyl hexanoate, octanal, *p*-cymene, limonene, cyclohexyl acetate, 2-phenylacetaldehyde, salicylaldehyde, (*E*)-β-ocimene, γ-terpinene, acetophenone, *trans*-linalool oxide (furanoid), *p*-tolualdehyde, terpinoiene, *p*-cymenene, 2-nonanone, methyl benzoate, ethyl heptanoate, nonanal, *p*-mentha-1,3,8-triene, isophorone, 1-phenyl-2-propanone, *cis*-limonene oxide, *trans*-limonene oxide, camphor, (*Z*)-3-hexenyl isobutyrate, citronellal, ethyl benzoate, ethyl octanoate, α-terpineol, methylthymol, neral, cuminaldehyde, carvone, ethyl 2-phenylacetate, edulan I, (*E*)-2-decenal, geranial, ethyl salicylate, perillaldehyde, (*E*)-anethole, isobornyl acetate, safrole, edulan II, benzyl butyrate, α-terpinyl acetate, citronellyl acetate, eugenol, γ-nonalactone, neryl acetate, benzyl isothiocyanate, α-ylangene, biphenyl, geranyl acetate, hexyl hexanoate, β-cubebene, β-elemene, ethyl decanoate, methyl eugenol, α-cedrene, *cis*-α-bergamotene, β-caryophyllene, (*E*)-α-ionone, *trans*-α-bergamotene, 2-phenylethyl butyrate, benzyl valerate, α-humulene, geranyl acetone, geranyl propionate, *ar*-curcumene, valencene, (*E*,*E*)-α-farnesene, γ-cadinene, δ-cadinene, α-calacorene, (*E*)-nerolidol, γ-undecalactone, dodecanoic acid, ethyl dodecanoate, hexadecane, methyl tridecanoate, dill apiol, 7-dodecalactone, heptadecane, 8-dodecalactone, methyl tetradecanoate, tetradecanoic acid, ethyl tetradecanoate, pentadecanoic acid, hexadecanoic acid, isopropyl hexadecanoate, methyl octadecanoate, oleic acid, octadecanoic acid, ethyl octadecanoate	[142]
Marula Intact Fruits	Head Space Solid Phase Microextraction	South Africa	ethyl isovalerate, ethyl hexanoate, ethyl octanoate, isoamyl hexanoate, ethyl (*E*)-4-octenoate, pentadecane, cyclopentadecane, β-caryophyllene, hexadecene, isoamyl octanoate, α-humulene, ethyl (*E*)-4-decenoate, heptadecane, (*Z*)-3-decenyl acetate, heptadecene, benzyl acetate, (*Z*)-3-decen-1-ol, 1-octen-3-yl butyrate, benzyl butyrate, nonadecane, 6-dodecen-1-ol, cyclodecene, benzyl methacrylate, benzyl 4-methylpentanoate, benzyl tiglate, hexadecanal, 11-hexadecenal, ethyl 9-hexadecenoate, benzyl octanoate, (*Z*)-13-octadecenal	[148]
Marula Fruit Pulp	Head Space Solid Phase Microextraction	South Africa	germacrene D, α-humulene, β-caryophyllene	[148]

Table 1. *Cont.*

Carrier Oil	VOC Extraction Method	Origin	Volatile Organic Compounds	Ref.
Moringa Leaves	Head Space Solid Phase Microextraction	Rwanda	(*E*)-2-pentenal, 2-hexenal, (*Z*)-2-heptenal, nonanal, (*E*,*E*)-2,4-hexadienal, (*E*,*E*)-2,4-heptadienal, benzaldehyde, (*E*)-2-nonenal, 2-phenylacetaldehyde, γ-nonalactone, 1-pentanol, (*Z*)-2-pentenol, hexanol, (*Z*)-3-octenol, octanol, 3,3-dimethylcyclohexanol, (*E*)-2,6-dimethyl-3,5,7-octatriene-2-ol, 1-pentadecanol, 1-nonanol, 1-undecanol, benzyl alcohol, phenethyl alcohol, methylheptenone, (*E*,*E*)-3,5-octadien-2-one, methyl heptadienone, 2-hexen-4-olide, 2-acetylpyrrole, 3-ethyl-4-methyl-1*H*-pyrrole-2,5-dione, dihydroactinidolide, tridecane, pentadecane, 1-tridecyne, heptadecane, methyl hexanoate, dibutyl phthalate, α-himachalene, (*E*)-geranyl acetone, (*E*)-β-ionone, β-ionone epoxide, hexahydrofarnesyl acetone, (*E*,*E*)-farnesyl acetone, acetic acid, dimethylpropanedioic acid, pentanoic acid, 3-methylbutanoic acid, pentanoic acid, hexanoic acid, 4-hexenoic acid, 2-hexenoic acid, octanoic acid, nonanoic acid, decanoic acid, dodecanoic acid, octadecanoic acid, tetradecanoic acid, (*E*)-9-octadecenoic acid, hexadecanoic acid, phenylacetonitrile	[238]
Moringa Leaves	Head Space Solid Phase Microextraction	China	(*E*)-2-butenal, hexanal, 2,4-pentadienal, (*E*)-2-pentenal, 2-hexenal, (*Z*)-2-heptenal, (*E*,*E*)-2,4-hexadienal, 2-methylfuran, 2-ethylcyclobutanol, (*Z*)-2-pentenol, (*E*)-2-ethyl-2-hexen-1-ol, 2,4-dimethylcyclohexanol, 3,3-dimethylcyclohexanol, benzyl alcohol, 1-dodecanol, methylheptenone, 1-(furan-2-yl)ethanone, (*E*,*E*)-3,5-octadien-2-one, γ-butyrolactone, 4-isopropyl-2-cyclohexenone, 2-hexen-4-olide, 2-acetylpyrrole, 7-octen-2-one, 3-ethyl-4-methyl-1*H*-pyrrole-2,5-dione, dihydroactinidolide, tridecane, 2-methyltridecane, pentadecane, 2-methyltetradecane, 2-methyl-1-tetradecene, 3-methylpentadecane, [*R*,*R*-(*E*)]-4,5-dimethyl-2-undecene, (*Z*)-hexyl oleate, methyl acetate, hexyl 3-methylbutanoate, (*Z*)-3-hexen-1-yl valerate, propyl 3-methylbutanoate, octyl 2-methyl butyrate, diethyl phthalate, dibutyl phthalate, *o*-cymene, α-himachalene, longifolene, carvone, citronellyl valerate, (*E*)-geranyl acetone, (*E*)-β-ionone, β-ionone epoxide, acetic acid, propionic acid, butyric acid, pentanoic acid, hexanoic acid, octadecanoic acid, (*E*)-9-octadecenoic acid, hexadecanoic acid, toluene, 2,4-lutidine, dimethylsulfoxide	[238]
Neem Seed (hydrodistillation)	GC-MS with PDMS coated column	India	1,3-propanedithiol, allyl mercaptan, 1-dodecene, 4,6-dimethyl-[1–3]trithiane, 1,3-propanedithiol, 3,5-diethyl-1,2,4-trithiolane, 1-hexadecanol, 2-*epi*-α-funebrene, *cis*-α-bergamotene, γ-muurolene, β-acoradiene, 5,6-dihydro-2,4,6-triethyl-4*H*-1,3,5-dithiazine, cycloisolongifolene, valencene, α-bisabolene, di-*tert*-butylphenol, (*E*)-nerolidol, 1-hexadecanol, juniper camphor, (*E*)-15-heptadecenal, oxacycloheptadec-8-en-2-one, (8*Z*)-cycloeicosane, 4,6-diethyl-1,2,3,5-tetrathiolane, 1-Tetracosanol, 9-hexacosene	[156]
Olive Oil, Cailletier Variety	Head Space Solid Phase Microextraction	France	ethanol, propan-2-one, pent-2-ene, acetic acid, pentan-2-one, pentan-3-one, heptane, 3-methylbutanol, pent-2-enal, (*Z*)-pent-2-enol, toluene, hex-3-enal, hexanal, octane, (*E*)-hex-2-enal, (*Z*)-hex-3-enol, (*E*)-hex-2-enol, hexanol, *p*-xylene, hexa-2,4-dienal, *o*-xylene, 3,4-diethylhexa-1,5-diene, benzaldehyde, α-pinene, 3-ethylocta-1,5-diene, octanal, (*Z*)-hex-3-enyl acetate, deca-3,7-diene, δ-3-carene, α-terpinene, limonene, β-Ocimene, γ-terpinene, nonanal, (*Z*)-4,8-dimethylnona-1,3,7-triene, farnesene	[239]
Olive Oil, Blanquettier Variety	Head Space Solid Phase Microextraction	France	ethanol, pent-2-ene, acetic acid, pentan-2-one, pentan-3-one, 3-methylbutanol, toluene, hexanal, octane, (*E*)-hex-2-enal, (*Z*)-hex-3-enol, (*E*)-hex-2-enol, hexanol, *p*-xylene, hexa-2,4-dienal, benzaldehyde, α-pinene, 3-ethylocta-1,5-diene, (*Z*)-hex-3-enyl acetate, deca-3,7-diene, β-ocimene, nonanal, (*Z*)-4,8-dimethylnona-1,3,7-triene, farnesene	[239]

Table 1. *Cont.*

Carrier Oil	VOC Extraction Method	Origin	Volatile Organic Compounds	Ref.
Olive Oil, Arbequines Variety	Head Space Solid Phase Microextraction	Spain	ethanol, pent-2-ene, qcetic acid, pentan-2-one, pentan-3-one, 3-methylbutanol, pent-2-enal, toluene, hexanal, octane, (*E*)-hex-2-enal, (*Z*)-hex-3-enol, (*E*)-hex-2-enol, hexanol, *p*-xylene, α-pinene, 3-ethylocta-1,5-diene, (*Z*)-hex-3-enyl acetate, hexyl acetate, β-ocimene, nonanal, (*Z*)-4,8-dimethylnona-1,3,7-triene, farnesene	[239]
Passionfruit Fruit Pulp	Head Space Solid Phase Microextraction	Brazil	methyl acetate, ethyl acetate, methyl butanoate, methyl (*E*)-2-butenoate, ethy butanoate, ethyl (*E*)-2-butenoate, methyl-2-pentenoate, methyl 3-hydroxybutanoate, propyl butanoate, methyl hexanoate, methyl 2-hexenoate, butyl butanoate, ethyl hexanoate, ethyl-2-hexenoate, methyl benzoate, hexyl butanoate, octyl acetate, hexyl (2*E*) butenoate, ethyl (*E*)-2-octenoate, methyl geranate, benzyl butanoate, methyl (*E*)-cinnamate, hexyl hexanoate, octyl butanoate, hexyl octanoate, methyl dihydrojasmonate, δ-3-carene, *p*-cymene, limonene, (*Z*)-β-ocimene, (*E*)-β-ocimene, γ-terpinene, α-terpinolene, 1,3,8-*p*-menthatriene, *allo*-ocimene, *neo-allo*-ocimene, bornylene, β-cyclocitral, β-ionone, 1-hexanol, 6,10-dimethyl-2-undecanone	[240]
Passionfruit Seed Oil (expeller extraction)	Head Space Solid Phase Microextraction	Brazil	ethyl 2-butenoate, methyl 2-butenoate, ethyl acetate, ethyl 3-hydroxybutanoate, methyl 3-butenoate, methyl butyrate, 2-methylbutanal, 3-methylbutanal, acetaldehyde, phenylacetaldehyde, hexanal, isobutanal, 3-methyl-1-butanol, 2-methyl-1-butanol, phenylethyl alcohol, 2-(3*H*)dihydrofuranone, (*E*)-β-ocimene, dodecane	[171]
Pomegranate Seed Oil (cold pressed)	Head Space Solid Phase Microextraction	Turkey	3-methyl-1-butanol, 2,3-butanediol, phenylethyl alcohol, ethyl butanoate, ethyl 2-hydroxy-propanoate, pentyl acetate, 1-butanyl 2-methylacetate, ethyl hexanoate, hexyl acetate, diethyl butanedioate	[241]
Pomegranate Seed Oil (cold pressed)	Head Space Solid Phase Microextraction	Israel	2,3-butanediol, phenylethyl alcohol, 1-pentanol, 2,4-nonadienal, 2-hexenal, (*Z*)-2-heptenal, hexanal, 5-decanone, pentanoic acid, hexanoic acid, limonene	[241]
Prickly Pear Seed Oil (hexane extract)	Head Space Solid Phase Microextraction	Greece	(2*Z*)-heptenal, hexanal, (2*E*)-octenal, 2-pentylfuran, (2*E*,4*E*)-decadienal, nonanal	[242]
Evening Primrose Oil	Head Space Solid Phase Microextraction	China	(*E*)-2-octen-ol, 2-ethyl-1-hexanol, 2-propanol, 1-octen-3-ol, 3-methyl-1-pentanol, 1-butanol, (*E*)-2-heptenal, nonanal, hexanal, (*E*)-2-nonenal, (*E*,*E*)-2,4-dodecadienal, (*E*,*E*)-2,4-decadienal, (*E*)-2-octenal, octanal, (*Z*)-9,17-octadecadienal, dodecanal, pentanal, heptanal, (*E*,*E*)-2,4-nonadienal, (*E*)-2-decenal, (*E*,*Z*)-2,4-decadienal, 2-tridecanone, 3-octen-2-one, 1-nonen-3-one, 2-hexenoic acid, 2-octynoic acid, acetic acid, heptanoic acid, hexanoic acid, octadecanoic acid, docosyl docosanoate, methyl (*Z*,*Z*)-9,12-octadecadienoate, methyl hexadecanoate, (*Z*)-9-octadecenyl octadecanoate, 4,6-dimethyldodecane, 2,6,10-trimethyltridecane, (*E*)-3-octadecene, 3,7-dimethyldecane, dodecane, heptadecane, octadecane, pentane, 5-methyl-tetradecane, tridecane, undecane	[183]
Pumpkin Seeds	Hydro-distillation	Ethiopia	2-phenylbut-2-enal, 2-phenylacetaldehyde, nonanal, decanal, (2*E*,4*E*)-deca-2,4-dienal, hexadecanal, 1-nonanol, 2,4-di-*tert*-butylphenol, 2-ethyl-1-hexanol, eicosane, hexacosane, (*E*)-undec-3-ene, hexadecane, 9-methylnonadecane, heptadecane, heneicosane, 5-butylhexadecane, [2,2,4-trimethyl-3-(2-methylpropanoyloxy)pentyl] 2-methylpropanoate, (3-hydroxy-2,4,4-trimethylpentyl) 2-methylpropanoate, methyl hexadecanoate, methyl 9-octadecenoate, Methyl octadecanoate, 1,8-cineole, δ-3-carene, (*E*)-geranyl acetone, 5,6-dihydro 2,4,6-trimethyl-4*H*-1,3,5-dithiazine, 1,3-benzothiazole, 2-hexylthiophene	[189]

Table 1. *Cont.*

Carrier Oil	VOC Extraction Method	Origin	Volatile Organic Compounds	Ref.
Pumpkin Seed Oil	Purge and Trap Extraction	Italy, Slovenia	methanol, scetaldehyde, methanethiol, methylformate, ethanol, acetone, pentane, ethyl formate, dimethylsulfide, methylacetate, carbon disulfide, dimethylsulfone, isobutanal, 2-butenal (crotonal), 2,3-butanedione, butanal, 2-butanone, hexane, ethyl acetate, isobutanol, 3-methylbutanal, 2-pentanone, butyl formate, 2-methylbutanal, 1-penten-3-ol, pentanal, heptane, 2-methyl-2-butenal, dimethyldisulfide, 1-pentanol, 2-hexanone, hexanal, 4-octene, 2-methyltetrahydrofuran-3-one, 2-methylpyrazine, furfural, 4-hydroxy-4-methyl-2-pentanone, 2-hexenal, 2-heptanone, heptanal, 2,6-dimethylpyrazine, α-pinene, 2-heptenal, 6-methyl-5-hepten-2-one, 2-octanone, dimethyltrisulfide, 2-pentylfuran, octanal, 5-methyl-2-ethylpyrazine, limonene, nonanal, fenchone	[186].
Raspberry Seeds (sonication)	Head Space Solid Phase Microextraction	Poland	(*E*,*E*)-3,5-heptatriene, 1,6-heptadien-4-ol, 3-methyl-1 butanol, 3-methyl-1-butanyl acetate, 2-methyl-1-propanol, (*E*)-2-hexenal, 3-methyl-3-buten-1-ol, (Z)-3-hexen-1-yl acetate, methyl acetate, benzene, ethanol, ethyl acetate, hexanal, 2,2-dimethylpropanal, propylene oxide, *p*-xylene	[109].
Rosehip *R. dumalis* fruit	Head Space Solid Phase Microextraction	Turkey	acetic acid, butanoic acid, 3-eethylpentanoic acid, oxalic acid, 2(3*H*)-furanone, 2-heptanone, 1-hydroxy-2-propanone, hexanal, 2-hexenal, acetaldehyde, nonanal, furfural, decanal, benzaldehyde, dodecanal, isoamyl isovalerate, butyl hexanoate, hexyl hexanoate, 1,2-propanediol, 1-penten-3-ol, 2-methyl-1-propanol, 3-methyl-1-butanol, 1-pentanol, 2-nonen-1-ol, 4-hexen-1-ol, 2-furanmethanol, 3,7-dimethyl-1,6-octadien-3-ol, 2-ethyl-1-hexanol, dodecanol, α-terpineol, 1-butanol, 2,4-bis(1,1-dimethylethyl)phenol, phenol, *m*-xylene	[198]
Rosehip *R. canina* fruit	Head Space Solid Phase Microextraction	Turkey	formic acid, acetic acid, ionone, 3-methylbutanoic acid, butanoic acid, 2-methyl-2-propenoic acid, hexanoic acid, heptanoic acid, octanoic acid, nonanoic acid, decanoic acid, 2(3*H*)-furanone, 6-methyl-5-hepten-2-one, hexanal, acetaldehyde, benzaldehyde, ethyl acetate, methyl acetate, hexyl hexanoate, 1,2-propanediol, 2-methyl-1-propanol, 3-methyl-1-butanol, 1-pentanol, 4-methyl-1-heptanol, 2-furanmethanol, 3,7-dimethyl-1,6-octadien-3-ol, α-terpineol, phenylethyl alcohol, 1-hexadecanol, α-humulene, naphthalene, 2,4-di-*tert*-butylphenol, phenol, *m*-xylene	[198]
Rosehip *R. pimpinellifolia* fruit	Head Space Solid Phase Microextraction	Turkey	2,4-dimethoxycinnamic acid, sinapic acid, formic acid, acetic acid, ionone, 3-methylbutanoic acid, hexanoic acid, octanoic acid, nonanoic acid, decanoic acid, benzoic acid, dodecanoic acid, 1,2-benzenedicarboxylic acid, Aacetone, 6-methyl-5-hepten-2-one, 1-hydroxy-2-propanone, 2*H*-pyran-2,6(3*H*)-dione, furfural, 3-caren-10-al, 2-nonen-1-ol, 2-furanmethanol, naphthalene, 2,4-di-*tert*-butylphenol, phenol	[198]
R. villosa	Head Space Solid Phase Microextraction	Turkey	formic acid, acetic acid, 3-methylbutanoic acid, butanoic acid, hexanoic acid, octanoic acid, benzoic acid, 1,2-benzenedicarboxylic acid, pentadecanoic acid, 2(3H)-furanone, 6-methyl-5-hepten-2-one, 1-hydroxy-2-propanone, furfural, benzaldehyde, ethyl acetate, ethanol, 3-methyl-1-butanol, 1-pentanol, 2-furanmethanol, 3,7-dimethyl-1,6-octadien-3-ol, α-terpineol, α-humulene, naphthalene, 2,4-di-*tert*-butylphenol, phenol	[198]
Rosehip Oil	Superheated Water Extraction	NA	benzaldehyde, benzyl alcohol, phenyl ethyl alcohol, 2,6,11-trimethyl dodecane and eicosane	[243]

Table 1. *Cont.*

Carrier Oil	VOC Extraction Method	Origin	Volatile Organic Compounds	Ref.
Dincer Safflower Seed Oil (cold pressed)	Head Space Solid Phase Microextraction	Turkey	acetoin, toluene, pentanal, 2,3-butanediol, hexanal, 2-hexenal, ethylbenzene, *p*-xylene, heptanal, γ-butyrolactone, α-pinene, *p*-cymene, limonene, benzyl alcohol, 1,5-octadien-3-ol, benzene acetaldehyde, 2-octenal, heptadecanoic acid, thiazolidine, 2-hepten-1-ol, nonanal, phenylethyl alcohol, 2-nonenal, 2,4-nonadienal, octanoic acid, 4-ethylbenzaldehyde, naphthalene, decanal, (*E*,*E*),-2,4-nonadienal, γ-octalactone, 3-dodecen-1-al, 6-dodecanone, thymol, 2,4-decadienal, undecanal, (*E*,*E*)2,4-decadienal, 5-pentyl-2(5*H*)-furanone, 2-dodecenal, 2-cyclohexen-1-one, 4-heptenal, 5-tetradecene, 1-tetradecene, 5,5-dimethyl-4(3-oxo-butyl)-2(3*H*)-furanone, methyl eugenol, dodecanal, β-caryophyllene, (*Z*)-geranyl acetone, tetradecanal, 2,4-dodecadienal, nonylbenzene, 17-octadecenal, isopropyl myristate, γ-dodecalactone, methyl 9-octadecenoate	[244]
Microwaved Dincer Safflower Seed Oil (cold pressed)	Head Space Solid Phase Microextraction	Turkey	2-methyl-1-butanol, pentanal, acetoin, pyrazine, 1-pentanal, 2,3-butanediol, hexanal, methylpyrazine, furfural, ethylbenzene, *p*-xylene, heptanone, heptanal, 2,5-dimethylpyrazine, methyl hexanoate, 2-ethylpyrazine, α-pinene, *p*-cymene, limonene, 1,5-octadien-3-ol, benzene acetaldehyde, 1-ethyl-2-formylpyrrol, 2-octenal, thiazolidine, 3,5-dimethyl-2-ethylpyrazine, 1-propylpentyl butyrate, nonanal, phenylethyl alcohol, 2-acetyl-6-methylpyrazine, (*E*)-3-nonene-2-one, 2-nonenal, 2,4-nonadienal, octanoic acid, naphthalene, 2-methyl-5*H*-6,7-dihydrocyclopentapyrazine, decanal, (*E*,*E*)-2,4-nonadienal, γ-octalactone, 3-dodecen-1-al, γ-nonalactone, 2,4-decadienal, undecanal, (*E*,*E*)-2,4-decadienal, 5-pentyl-2(5*H*)-furanone, 2-dodecenal, 2-cyclohexen-1-one, 4-heptenal, 5-tetradecene, 1-tetradecene, 5,5-dimethyl-4(3-oxo-butyl)-2(3*H*)-furanone, methyl eugenol, dodecanal, 2,4-undecadienal, β-caryophyllene, (*Z*)-geranyl acetone, tetradecanal, 2,4-dodecadienal, lauric acid, nonylbenzene, myristic acid, 17-octadecenal, isopropyl myristate, γ-dodecalactone, methyl 9-octadecanoate	[244]
Roasted Dincer Safflower Seed Oil (cold pressed)	Head Space Solid Phase Microextraction	Turkey	isoamyl alcohol, toluene, 2,3-butanediol, hexanal, 2-hexenal, ethylbenzene, *p*-xylene, heptanal, γ-butyrolactone, α-pinene, α-phellandrene, *p*-cymene, limonene, 1,5-octadien-3-ol, 2-octenal, isophytol, nonanal, phenylethyl alcohol, 2-nonenal, 2,4-nonadienal, octanoic acid, naphthalene, (*E*,*E*)-2,4-nonadienal, 3-dodecen-1-al, γ-nonalactone, 6-dodecanone, 2,4-decadienal, 2-*n*-heptylfuran, undecanal, (*E*,*E*)-2,4-decadienal, 2-dodecenal, 2-cyclohexen-1-one, 5-tetradecene, 1-tetradecene, 5,5-dimethyl-4(3-oxo-butyl)-2(3*H*)-furanone, methyl eugenol, 2,4-undecadienal, β-caryophyllene, tetradecanal, 2,4-dodecadienal, lauric acid, nonylbenzene, 17-octadecenal, γ-dodecalactone, methyl 9-octadecanoate	[244]
Sesame Seed Oil (Screw-Press Extraction)	Head Space Solid Phase Microextraction	China	pentanal, hexanal, heptanal, benzaldehyde, octanal, benzeneacetaldehyde, (*E*)−2-octenal, nonanal, decanal, 2-heptanone, 6-methyl−5-hepten−2-one, 3-octanone, 3-methyl−1-butanol, 1-pentanol, 1-heptanol, 1-octanol, acetic acid, pyridine, ethyl-pyrazine, trimethyl-pyrazine, methyl-pyrazine, 3-ethyl−2,5-dimethyl-pyrazine, 2-methoxy−3-(2-methylpropyl)-pyrazine, dimethyl sulfide, dimethyl disulfide, dimethylsulfoxide, 2,4-dimethylthiazole, butyrolactone	[245]
Roasted Sesame Seed Oil	GC-FID with Carbowax coated column	Korea	1-octen-3-ol, 3-methyl-2-butanone, furfuryl alcohol, guaiacol, 2-methylpyrazine, 2,5-dimethylpyrazine, 2,6-dimethylpyrazine, 2,3,5-trimethylpyrazine, pyrazine, 2-ethylpyrazine, 2-acety1pyrazine, 2-acetyl-5-methylpyrazine, 2-ethyl-6-methylpyrazine, 2,3-dimethylpyrazine, pyrrole, 2-acetylpyrrole, 2-pyrrolecarbaldehyde	[246]

Table 1. *Cont.*

Carrier Oil	VOC Extraction Method	Origin	Volatile Organic Compounds	Ref.
Shea Butter (cold pressed)	Purge and Trap Extraction	Ivory Coast	2-methylbutanal, 3-methylbutanal, (*Z*)-2-hexenal, (*E*)-2-hexenal, (*E*)-2-heptenal, (*Z*)-6-nonenal, benzaldehyde, (*E*,*E*)-2,4-nonadienal, (*E*,*E*)-2,4-decadienal, 4-methoxybenzaldehyde, 1-penten-3-ol, 3-hexanol, 1-hexanol, 2-methyl-2-butenol, 2-heptanol, (*E*)-2-hexenol, 3-octanol, 2,3-butanediol, benzyl alcohol, phenylethyl alcohol, 3-methoxy-2-butanol, 4-methyl-3-penten-2-one, 3-hydroxy-2-butanone, acetophenone, ethyl acetate, butyl acetate, acetic acid, propanoic acid, butyric acid, valeric acid, hexanoic acid, heptanoic acid, nonanoic acid, 2-methylfuran, gurfural, 2-scetylfuran, 2-hydroxymethylfuran, α-pinene, sabinene, α-terpinene, limonene, *p*-cymene, β-myrcene, phenol, *p*-cresol, *o*-xylene, styrene, γ-butyrolactone, 2-acetylpyrrole, 2-ethylpyrazine, 2-acetyl-3-methylpyrazine	[247]
Shea Butter (Solvent extraction)	Purge and Trap Extraction	Ivory Coast	2-methylbutanal, 3-methylbutanal, (*Z*)-2-hexenal, (*E*)-2-hexenal, (*E*)-2-heptenal, (*Z*)-6-nonenal, benzaldehyde, (*E*,*E*)-2,4-nonadienal, (*E*,*E*)-2,4-decadienal, 4-methoxybenzaldehyde, 1-penten-3-ol, 3-hexanol, 1-hexanol, 2-methyl-2-butenol, 2-heptanol, (*E*)-2-hexenol, 3-octanol, 2,3-butanediol, benzyl alcohol, phenylethyl alcohol, 3-methoxy-2-butanol, 4-methyl-3-penten-2-one, 3-hydroxy-2-butanone, acetophenone, pheny lacetate, acetic acid, propanoic acid, butyric acid, valeric acid, hexanoic acid, heptanoic acid, nonanoic acid, furfural, α-pinene, sabinene, α-terpinene, limonene, *p*-cymene, β-myrcene, phenol, *o*-xylene, styrene, γ-valerolactone, γ-butyrolactone, 2-acetylpyrrole, 2-ethylpyrazine, 2-acetyl-3-methylpyrazine	[247]
Shea Butter	Purge and Trap Extraction	Ivory Coast	2-methylbutanal, 3-methylbutanal, (*E*)-2-heptenal, benzaldehyde, (*E*,*E*)-2,4-nonadienal, 1-penten-3-ol, 3-hexanol, 1-hexanol, 2-methyl-2-butenol, 2-heptanol, 3-cctanol, 2,3-butanediol, benzyl alcohol, phenylethyl alcohol, ethyl acetate, butyl acetate, phenyl acetate, acetic acid, propanoic acid, butyric acid, valeric acid, hexanoic acid, heptanoic acid, nonanoic acid, 2-methylfuran, furfural, 2-acetylfuran, 2-hydroxymethylfuran, α-pinene, sabinene, α-terpinene, limonene, *p*-cymene, guaiacol, phenol, *p*-cresol, *o*-xylene, styrene, γ-valerolactone, γ-butyrolactone, 2-acetylpyrrole, 2-ethylpyrazine, 2-acetyl-3-methylpyrazine	[247]
Soy Bean Oil (expeller extraction)	Vacuum-Assisted Head Space Solid Phase Microextraction	China	hexanal, (*Z*)-2-heptenal, nonanal, decanal, (*E*)-2-hepten-1-ol, (*E*,*E*)-3,5-octadien-2-one, toluene, ethylbenzene, *p*-xylene, styrene, butyl butanoate	[248]

42. Conclusions

Aromatherapy is an increasingly popular complementary and alternative treatment, and many essential oils are used in conjunction with carrier oils. However, many volatile components of carrier oils may have offensive organoleptic properties (e.g., dimethyl sulfide, dimethyl disulfide, butyric acid) or unacceptable toxicities (e.g., benzene). Furthermore, there are several components reported that are likely contaminants (e.g., 2,4-di-*tert*-butylphenol, diethyl phthalate, dibutyl phthalate) rather than actual carrier oil components. It is also useful to know if the contaminants that are present in the carrier oils to be used have undesirable side effects (e.g., phthalate esters have shown anti-estrogenic activities and developmental and reproductive toxicity). Future studies should be carried out to verify the volatile components of carrier oils, determine variability in the volatile components based on origin, and assess possible contamination or adulteration. Interestingly, no information was available about the volatiles of babassu, baobab, chia, hazelnut, jojoba, kukui nut, palm kernel, sacha inchi, sea buckthorn berry, shea butter, sunflower, and tamanu. Additional research is needed in order to determine the volatile components of these oils as well as any forthcoming carrier oils. This review has presented a compilation of volatile components of carrier oils and includes evaluation of extraction methods. The information serves to identify gaps in information regarding carrier oils and should provide guidance for future research into new carrier oils and new extraction methodology.

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