EXTRACTION OF OILS FROM FRUIT KERNELS WITH CONVENTIONAL AND INNOVATIVE METHODS: A REVIEW

SCIENTIFIC REVIEW ARTICLE

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ABSTRACT:
Over recent years, the food industry has striven to reduce waste, mostly because of rising awareness of the detrimental environmental impacts of food waste. While the edible oils market is enlarging constantly, there is increasing interest in producing plant-based oils because of the presence of various bioactive components like mono and poly unsaturated fatty acids. In recent publications it has been shown that various fruit kernels represent source of these components while the conversion of bio-waste into valuable compounds is of outmost importance for ensuring sustainability of the environment. This review investigates the different methods used for extraction of oils from sour cherry, peach, apricot and olive kernels and comparison between these methods in terms of extraction yield, fatty acids profile, tocopherols yield and antioxidant activity. An overview of chemical composition, bioactivity and on the application of these oils in end markets such as cosmetics, pharmaceuticals and nutraceuticals is presented. Scientific databases such as PubMed, Scopus, Google Scholar, Research Gate, ClinicalTrials have been used to assemble the data for this review.

KEYWORDS: extraction, oil, sour cherry, apricot, peach, olive

INTRODUCTION

The expansion of the world population has caused higher demand for food, resulting in the constantly expanding production of various fruits, vegetables and cereals. Consequently, with increased food processing, there has been a significant growth in agricultural waste leading to adverse environmental effects and economic losses. Up to 30% of all crops are discarded amounting to hundreds of thousands of tons annually of discarded fruit across the sector.
In the literature, various fruit wastes, including seeds, peels, pomace, stems, leaves, and stones were evaluated according to their chemical compositions, and remarkable amounts of bioactive components were identified [1]-[5]. Besides fruit wastes, the kernels of some tree crops apricot, almond, walnut, hazelnut, peach can also be utilized for oil extraction purposes for edible and non-edible uses. The oils of tree fruits and kernels are also becoming popular very fast for various foods, pharmaceutical and cosmetic industries [6].

The extraction of bioactive components from various fruit wastes ensuring high extraction efficiency without further utilization of hazardous chemicals is challenging in order to improve the sustainability of the food system [7].

Conventional extraction methods are generally based on an organic solvent, often confronted as liquid−liquid or solid−liquid extraction methods. On the one hand, in addition to organic solvent usage, another disadvantage of these techniques is the incorporation of an evaporation step, which cannot be ignored due to a high possibility of thermal destruction of bioactive components [8]. On the other hand, novel "green" methods recently emerged in the literature, which can be listed as microwave-assisted extraction (MAE), pulsed electric field (PEF), ultrasound-assisted extraction (UAE), supercritical fluid extraction (SC-CO_2), enzyme-assisted extraction (EAE), and pressurized liquid extraction (PLE) [9]. A proper extraction method should be chosen with outmost care to enable careful extraction with no chemical alteration.

In this regard, this review emphasizes the methods used for oil extraction from kernels of sour cherry, apricot, peach and olives, chemical composition and antioxidative activity. Cosmetic, nutraceutical and pharmaceutical applications of value-added products is also given.

METHOD

Searches of databases including PubMed, Scopus, Google Scholar, Research Gate, ClinicalTrials for scientific research papers were conducted. The keywords and terms used included extraction of oil and combinations of sour cherry, peach, apricot, olive kernel. As appropriate papers were identified, further search terms used were specific to industry sectors and applications. The papers selected were restricted to those published in English language. No geographical restrictions were applied. Some industry sectors and concepts were explored further using publicly accessible websites. To identify appropriate clinical trials, searches were conducted of the database ClinicalTrials.gov (U.S. National Library of Medicine). The search terms used were oil and sour cherry, peach, apricot and olive.

EXTRACTION OF OIL FROM SOUR CHERRY KERNEL

Sour cherries, species of *Prunus* in the subgenus *Cerasus*, are grown throughout the world at amounts about 1.2 million tons/year [10]. Sour cherries are mostly consumed as processed products, such as canned and frozen sour cherry, or sour cherry juice. During processing of sour cherries, high amounts of kernels arise as a waste material that could be used as a dietary fiber, protein, and fat source [11].

In the available literature different methods for extraction of oils from sour cherry kernel have been used starting from the conventional like cold press, Soxhlet extraction and innovative like superfluid extraction [12]-[24]. The dominant method used is Soxhlet with nonpolar solvents like n-hexane and petroleum ether.

Table 1. Extraction of sour cherry kernel oil

Extraction yield (%)	Method	Fatty acid composition (%)							Location	Reference
		C18:1	C18:2	C18:3	C16:1	C16:0	C18:0	C20:0		
ND	SE	43.9	44.8	0.48	0.44	7.8	2.4	0.73	Iran	[12]
ND	SE	52.9	35.0	ND	0.3	7.6	2.3	1.4	Canada	[13]
ND	SE	42.9	38.2	ND	ND	11	6.4	0.9	Romania	[14]
ND	SE	46.80±0.16	40.58 ±0.13	5.06 ±0.14	ND	6.23 ±0.15	1.33 ±0.13	ND	Turkey	[15]
ND	SC-CO_2	44.99±1.38	41.81 ±0.13	4.63 ±1.09	ND	7.24 ±0.16	1.33 ±0.12	ND		
ND	CP	35.45	42.34	0.13	0.50	6.54	2.03	0.87	Iran	[16]
ND	CP	37.89	42.42	0.11	0.29	4.92	1.60	0.64	Turkey	[17]
30.9	SE	47.62	33.47	0.12	0.63	8.18	2.46	0.90	USA	[18]
ND	SE	45.03±0.06	40.61 ±0.07	3.87 ±0.06	ND	5.93 ±0.04	3.3 ±0.05	1.26±0.37	Iran	[19]
32-36	SE	50-53	35-38	ND	ND	3-4	ND	ND	Hungary	[20]
55.95± 2.70	CP	35.28 ±2.16	40.19 ±1.97	ND	1.32 ±0.36	19.5 ±4.17	1.31 ±0.11	ND	Turkey	[21]
17.5-31.8	SE	25.3-45.3	35.5-46.1	0.09-0.48	0.16-0.33	5.1-7.4	2.2-3.4	1.0-1.4	Latvia	[22]
4.00	CP	41.92	46.82	0.33	0.38	6.35	2.27	1.10	Serbia	[23]
5.15	SE	41.46	47.00	0.33	0.37	6.62	2.21	1.12		
13.02	SC-CO_2	40.80	47.37	0.32	0.37	6.91	2.29	1.09		
ND	SE	46.9	41.7	/	/	9.4	2.0	ND	Bulgaria	[24]

The fatty acid composition is analyzed (Table 1) and the presence of various bioactive components (Table 2). Sour cherry kernel oil is rich in monounsaturated oleic acid and polyunsaturated linoleic acid (higher than 80%) while the dominant saturated fatty acids are palmitic and stearic (less than 15%). Other fatty acids like linolenic, palmitoleic, arachidic were found in very low concentrations.

Yilmaz and Gokmen [15] used two methods of extraction, namely Soxhlet and SC-CO_2 in which it was shown that the extraction method did not have a significant effect on the fatty acid profile. The study of Gornaś et al. [21] showed that the quantity of fatty

acids is affected by the cultivar of sour cherry. The difference in the composition of fatty acids in the oils extracted is due to different geographic locations and conditions in which the plants are grown.

Only in a few publications [16], [17], [22] the presence of α-eleostearic acid is reported. In sour cherry kernel oil of the cultivar Tamaris the presence of this fatty acid was 15.76% [22]. The compound is found to induce programmed cell death of fat cell [25] and of HL60leukemia cells in vitro at concentration of 20 μM [26].

BIOACTIVE COMPOUNDS IN SOUR CHERRY KERNEL OIL

Vitamin E is a group of eight compounds: α-, β-, γ-, δ-tocopherols and α-, β-, γ-, δ-tocotrienols, which are lipid-soluble [27]. All vitamin E isoforms, have antiproliferative, pro-apoptotic, anti-angiogenic, and anti-inflammatory effects [28].

Sour cherry kernel oil is rich in tocopherols and tocotrienols as it is shown in above cited articles, among them the predominant is γ-tocopherol [15]-[18], [21], [22]. Two tocotrienols α (0.5-2.2 mg/kg oil) and γ (0.1-0.4 mg/kg oil) were detected in sour cherry kernel oil in a study conducted by Gornaś et al. [22].

Phytosterols compounds are biologically active molecules with multiple health application such as reducing total and low-density lipoprotein (LDL) cholesterol levels [29]; have antioxidant, antiulcer, immunomodulatory, antibacterial, and antifungal effects [30].

Kazampour-Samak et al. [16] found that the most abundant sterol compounds were β-sitosterol (83.55%), Δ5-avenasterol (6.8%), sitostanol (4.8%), campesterol (3.5%), and stigmasterol (0.53%), respectively.

The sterol composition of sour cherry kernel oil consisted of 88.69% of β-sitosterol in total of thirteen sterols identified in the study of Atik et al. [17].

Nine sterols (campesterol, D-sitosterol, D5-avenasterol, 24-methylene-cycloartanol, cholesterol, gramisterol, D7-stigmasterol, D7-avenasterol, and citrostadienol) were quantified in a study of kernel oils of six sour cherry cultivars [22].

Table 2. Bioactive compounds present in sorry cherry kernel oil

Method	Tocopherols (mg/kg oil)				Sterols (%)			Carotenoids (mg/100 g oil)	Reference
	α	β	γ	δ	β-sitosterol	Campesterol	D5-avenasterol		
SE	71.6		298.7	96.9		ND		9.20	[15]
SC-CO_2	96.62		330.84	41.99		ND		5.93	
CP	325.00±3.29	ND	470.00±5.22	37.50 ±2.22	83.55±5.28	3.50 ±0.11	6.80 ±0.18	ND	[16]
CP	102.58	4.56	70.62	46.67	88.69	2.76	2.61	ND	[17]
SE	61.0	ND	400.0	64.2	44.5	2.55	ND	ND	[18]
CP	39.07± 0.23	ND	701.42±2.73	76.15 ±0.26	41	1.85	2.16	ND	[21]
SE	9.2-38.5	0.5-2.5	89.1-133.3	9.5-18.2	24.1-85.2	0.76-4.16	0.15-7.82	0.51-1.75	[22]
CP	6.39±0.08	1.07±0.25	25.22±0.05	5.41±0.18	ND	ND	ND	ND	[23]
SE	4.71±0.28	0.93±0.09	26.06±1.56	5.68±0.18	ND	ND	ND	ND	
SC-CO_2	6.25±0.34	1.00±0.06	23.85±1.46	5.13±0.25	ND	ND	ND	ND	

Carotenoids consumption in human diet reduces the risk of a variety of chronic illnesses, including cardiovascular diseases and neurological disorders, type 2 diabetes, and different types of cancer [31].

The findings of Yılmaz and Gokmen [15] proved that extraction method had an impact on β-carotene content in sour cherry kernel oil. Hexane extracted oil had significantly higher levels of β-carotene compared to oil extracted with SC-CO_2.

In sour cherry kernel oils from Latvia [22] only minor content of carotenoids were determined, with an average value of 0.94 mg/100 g oil and significant amounts of squalene (65.8–102.8 mg/100 g oil).

Phenols are bioactive compounds capable of scavenging free radicals and antioxidant activity. These compounds are abundantly found in plants and, as secondary metabolites, play an important role against oxidative stress [32].

Total phenolics were determined in the study of Yilmaz and Gokmen [15] which were in the range from 6.60 mg GAE/L to 27.87 mg GAE/L. The oil extracted with SC-CO_2 had higher content of total phenolic compounds.

The total phenolic content in extracted oil of sour cherry kernel was 33.44 mg GA/g dry matter [16].

Ten phenolic compounds were identified [17], phenolics acids levels were higher than other phenolic compounds. Benzoic acid (79.7 mg/kg), vanillin (5.62 mg/kg), p-coumaric acid (2.80 mg/kg), apigenin (1.82 mg/kg) were most abundant phenols in the SCKO.

EXTRACTION OF OIL FROM APRICOT KERNEL

Apricot (*Prunus armeniaca*), a member of the *Rosaceae* family, has been widely cultivated in Mediterranean countries as well as in Russia, Pakistan, the United States, and Iran [33]. The apricot kernel is a byproduct of apricot fruit and can be eaten as an appetizer (either raw or roasted) [34]. Nevertheless, the kernel is especially important for the oleo-chemical industry due to its valuable oil.

Table 3. Extraction of apricot kernel oil

Extraction yield (%)	Method	Fatty acid composition (%)							Location	Ref.
		C18:1	C18:2	C18:3	C16:1	C16:0	C18:0	C20:0		
ND	SE	64.4	26.9	0.1	0.8	6.7	1.1	ND	Bulgaria	[24]
39.8	SE				ND				India	[35]
Hexane: 47.8 Ether: 39.2 Acetone: 46.0 Ethanol: 30.3 Chlo:Met 54.6	SE	63.3-72.8	21.3-29.0	ND	0.5-0.8	4.0-5.7	1.2-1.5	ND	Turkey	[36]
32.44	CP-EAE				ND				India	[37]
35.6±0.97	CP	70.4 ±0.49	21.7 ±0.53	ND	0.6 ±0.03	6.1 ±0.13	1.2 ±0.08	ND	Turkey	[38]
45.9±0.34	SE	72.1 ±0.21	19.9 ±0.65	ND	0.5 ±0.06	6.4 ±0.04	1.1 ±0.07	ND		
36.78	CP	62.73	29.18	ND	ND	ND	ND	ND	Croatia	[39]
48.76	SC-CO_2	57.33	33.81	ND	ND	ND	ND	ND		
ND	SE	69.79 - 71.43	22.10-22.71	0.74-1.08	0.65-0.75	2.93-3.42	1.06-1.69	ND	Poland	[40]
32.9	CP	67.81	26.33	0.10	0.78	3.81	1.00	0.08	China	[41]
52	SE	67.96	26.21	0.13	0.69	3.83	0.99	0.07		
44	UAE	68.13	25.94	0.10	0.63	3.96	1.01	0.12		
52.7-54.4	SE	83.3	45.6	2.0	1.50	19	3.50	ND	Turkey	[42]
ND	SE	62.34 - 80.97	13.33-30.33	0.73-1.03	0.32-0.71	3.35-5.93	1.10-1.68	ND	Pakistan	[43]
ND	SE	58-65.7	29-33	0.5-1.0	1-2	4.6-6.0	0.5-1.20	0.2	USA	[44]
ND	SE	53.06 - 70.90	21.43-35.67	ND	ND	4.56-6.03	ND	ND	Turkey	[45]
ND	CP	70.90 ±0.00	20.93±0.00	0.74±0.00	ND	4.25±0.00	1.36±0.00	/	Macedonia	[46]

The apricot kernel oil contains more than 85% unsaturated fatty acids and less than 5% saturated fatty acids (table 3). Oleic acid is the main unsaturated acid followed by linoleic acid, while palmitoleic and linolenic only in few papers are reported with amounts less than 1%. The main saturated fatty acids are palmitic and stearic. In the published papers conventional methods like cold press and Soxhlet are mostly used for the extraction of oils from peach kernels with few reports of SC-CO_2 and ultrasonic [24], [35]-[46].

Iuata [38] showed that in comparison of two methods higher extraction yield was obtained with Soxhlet extraction (45.9%) simile to cold press (35.6%), but there was insignificant difference for fatty acid composition using two different extraction techniques.

In the study of Pavlović et al. [39] a comparison of the conventional cold press and the innovative SC-

CO_2 was performed. Higher extraction yield was obtained with SC-CO_2 (48.76%) to the cold press (36.78%) while not significant changes in the total content of unsaturated acids was observed.

Wang et al. [41] analyzed the three methods cold press, Soxhlet and ultrasonic assisted extraction. Among these higher efficiency of the extraction (52%) was obtained with Soxhlet using n-hexane as a solvent. The fatty acid profile was very similar in all the obtained oils.

Research group of Azcan and Demirel [36], Anwar et el. [43], Ozcan et al. [45] showed that the fatty acid composition of apricot kernel oil varies widely among different plant species.

BIOACTIVE COMPOUNDS IN APRICOT KERNEL OIL

Total tocopherols were determined in apricot kernel oil extracted with CP and SE methods. γ-tocopherol was determined as the main and the highest tocopherol isomer and α- tocopherol was determined as the secondary tocopherol isomer in both oils. δ- and β-tocopherol were determined in lower amount than the other isomers. The amount of γ- and α- tocopherol in CP-AKO was nearly 1.5-fold higher than that of SE-AKO. β- and δ- tocopherol in SE-AKO was higher than that of CP-ASO [38].

Pavlović et al. [39] obtained higher total content of tocopherols by CP, although α-tocopherol was extracted by SC-CO_2, while this was not achieved by the application of the cold press technique.

The results of the research presented [40] indicate that the apricot cultivar significantly influenced the content of tocopherols. Among the five tested apricot cultivars, the most valuable oil in terms of content of tocopherols was the oil obtained from the kernels of the 'Somo' cultivar.

In the study of Anwar et el. [43] tocopherol contents for apricot kernel oils exhibited a significant variation among the varieties analyzed. The highest concentration of α-tocopherol was exhibited for the apricot kernel oil of the variety Charmagzi (40.4 mg/kg) while the lowest was found for the variety Halmas (14.8 mg/kg). The contents of δ-tocopherol were found to be higher (60.2 mg/kg) in the variety Nari, whereas the lowest (28.5 mg/kg) was found for the variety Halmas, among others.

Rudzinska et al. [47] demonstrated in their study that AKO is a good source of diverse phytosterols (215-973.6 mg/100 g oil), β-sitosterol being the most abundant (76%–86% of total sterols). Low concentrations were recorded for campesterol, Δ5-avenasterol and cholesterol (11.2–48.7, 9.5–31.4 and 0.0–52.6 mg/100 g oil, respectively). For 24-methylene–cycloartanol, gramisterol, Δ7-stigmasterol, Δ7-avenasterol and citrostadienol were noted values below 10.2 mg/100 g oil.

Ramadan et al. [48] identified minor quantities (<35 mg/kg) of stigmasterol, D5, 24-stigmastanol, and D7-stigmastanol in cold pressed apricot kernel oil.
Stryezka et al. [40] showed that β-carotene content depends on the cultivar of the plant. The highest content of β-carotene was observed in the 'Somo' cultivar (66.8 μg/g oil), and the lowest in 'Goldrich Sungiant' (42.3 μg/g oil).

Apricot kernel oil extracted with SE had higher total phenolic content (26.9 μg gallic acid/g oil) than oil extracted with CP (24.9 μg/gallic acid/g oil) [40].
The content of polyphenols depended on the cultivar [42], the 'Somo' cultivar had the highest content of polyphenols (1.22 mM GAE/L), while 'Goldrich Sungiant' and 'Early Orange' had the least (0.85 and 0.87 mM GAE/L), respectively.

Table 4. Bioactive compounds present in apricot kernel oil

Method	Tocopherols (mg/kg oil)				Carotenoids (g/ 100 g oil)	Reference
	α	β	γ	δ		
CP	39.6	9.2	498.5	15.1	ND	[36]
SE	27.4	11.3	318.9	17.2		
CP	942				ND	[37]
SC	500					
SE	19.6-40.0	ND	315.4-502.3	28.3-58.5	42.3-66.8	[38]
SE	14.8-40.4	ND	330.8-520.8	28.5-60.2	ND	[41]
CP	/	/	550±0.2	19±0.0	ND	[46]

EXTRACTION OF OIL FROM PEACH KERNEL

Prunus persica is one of the species of the *Rosaceae* family that is widely distributed in most countries around the world. Peach is the second most important fruit crop in the European Union (EU) (approx. 3.8 million tons) after the apple [49]. The pulp from peaches is used directly for jams and canned food or diluted to prepare commercial or domestic

juices [50]. In addition, the leaves of the peach tree are used for the treatment of irritated digestive tract and constipation [51].

Table 5. Extraction of peach kernel oil

Extraction yield (%)	Method used for extraction	Fatty acid composition (%)							Location	Reference
		C18:1	C18:2	C18:3	C16:1	C16:0	C18:0	C20:0		
42.8	SE				ND				India	[35]
ND	SE	57.46	25.44	ND	ND	5.93	ND	6.18	Turkey	[45]
16-44	SE	52.5-72.9	18.51-26.1	0-0.06	0-0.30	6.0-14.8	2.25-5.1	0.05-0.15	Brazil	[54]
0.4-8.8	Mac	44.1-63	18-33.0	0-1.2	0-1	8.0-23	3.2-15.4	0-0.1		
0.17	HD	42.3	32.4	0	0	21.4	3.3	0		
3.80-24	SC-CO_2	67.6-79.7	15-19.90	0-1.1	0.21-0.9	5.9-9.2	2.26-2.6	0-0.2		
48	SE	74.6	15.7	0.1	0.5	6.0	2.1	0.2	Spain	[55]
30	SC-CO_2	72.6	17.7	0.0	0.6	6.6	1.9	0.1		
32	SC-CO_2 with ethanol	72.2	18.1	0.05	0.6	6.2	2.1	0.2		
Petroleum ether (g/g d.b) 0.25±0.04	SE	65.77 ±1.293	25.98 ±1.970	0.131 ±0.011	0.276 ±0.051	5.632 ±0.013	1.966 ±0.231	0.034 ±0.002	Canada	[56]
Chloroform 0.35±0.06		65.74 ±0.361	26.02 ±0.892	0.131 ±0.002	0.277 ±0.098	5.634 ±0.114	1.965 ±0.089	0.04 ±0.005		
Ethyl ether 0.38±0.07		65.76 ±2.034	25.89 ±0.099	0.132 ±0.007	0.280 ±0.016	5.691 ±0.086	1.983 ±0.007	0.034 ±0.006		
Hexane 0.26±0.04		61.87 ±0.068	29.07 ±0.013	0.161 ±0.000	0.252 ±0.001	6.355 ±0.035	1.917 ±0.011	0.038 ±0.003		
35.3	SC-CO_2				ND				Turkey	[57]
ND	SE	69.3	20.5	ND	0.4	6.1	1.9	0.0	Tunisia	[58]
ND	SE	59.8-64.6	27.9-32.8	0.31-0.42	0.53-0.69	4.13-5.82	1.25-1.44	ND	Pakistan	[59]
ND	SE	70.3	19.5	0.1	ND	5.9	1.6	0.1	Turkey	[60]

The kernel is considered an important food source with a high nutritional value, mostly due to its oil and protein contents [52] but they are usually destined to animal feed or used as fuel [53]. However, each year, thousands of tons of stones (pericarp plus kernel) from peaches are wasted as a by-product of the production of juices and jams.

Therefore, in the literature there are available papers which report extraction of oils from peach kernel [35], [45], [54]-[60] mostly with Soxhlet extraction using non-polar solvents. Few research groups have compared the conventional method with SC-CO_2 [54], [55].

In the study of Ferreira et al. [54] Soxhlet, maceration, hydro distillation and SC-CO_2 with different extraction solvents and key parameters in SC-CO_2 were tested. Among Soxhlet extractions, those carried out with DCM, EtAc and EtOH provided the highest yields, also the resulting extracts contained large variation in composition due to the broad range of polarity of solvents. The HD yield was the lowest value (0.17±0.02%), followed by Mac–EtAc, Mac–water and Mac–Hx (0.4±0.1%, 1.1±0.3% and 1.9±0.1%, respectively). The results for pure CO_2 indicated the maximum yield of 23.5 (0.4% (w/ w)) obtained at 50 ˚C/300 bar, with solvent density of 0.871 g CO_2/cm^3.

No differences in the composition of fatty acids profile were determined among different methods used, nevertheless higher yield of extraction was achieved with Soxhlet extraction in the study conducted by Pando et al. [55].

Higher yield of oil with ethyl ether was obtained in comparison with hexane, chloroform and petroleum ether with Soxhlet, although there was not observed a change in quantity of fatty acids [56].

Anwar et al. [59] showed that the fatty acids composition of kernel oils varies widely among different plant species.

These studies show that apricot kernel oil consists of more than 85% unsaturated fatty acids with the dominant oleic acid, besides palmitic and stearic acid being the main saturated fatty acids with amounts less than 10% (table 5).

BIOACTIVE COMPOUNDS IN PEACH KERNEL OIL

Pando et al. [55] with superfluid extraction determined γ-tocopherol and γ-tocotrienol; their contents in the oil extracted were 44 and 150 mg/kg, respectively. The other forms of tocopherol and tocotrienol were not detected.

In the study of Anwar et al. [56] quantity of tocopherols varied among different plant species. The corresponding contents of α-tocopherol, δ-tocopherol and γ- tocopherol in peach kernel oil ranged from 175.4-187.5, 74.5-85.9 and 110.2-126.7 mg/kg, respectively.

In the study of Ozcan and Mathaus [57] α-tocopherol was the dominating tocopherol with 37.3 mg/kg, followed by γ-tocopherol with 1.6 mg/kg. Also, α-tocotrienol was present in peach kernel oil with amount 24.0 mg/kg.

The amount β-sitosterol extracted from peach kernels was 1220 mg/kg kernel at optimal values of 40 °C, 200 bar, 7 ml/min, 0.3 mm and 3 hours [54].

The main phytosterol component in peach kernel oil was established to be β-sitosterol amounting 78.8-80.0% followed by Δ5-avenasterol with levels 8.9-12.2%. A considerable amount of campesterol and Δ7-avenasterol within the range of 4.1 to 5.9% was detected in the tested oils [56].

Total phenolic compounds were determined 128±5 mg GAE/g from SE-EtOH sample. Otherwise, the mixture (EtOH/water) in Soxhlet extraction resulted in a poor solvent for phenolic compounds, with TPC of 0.3±0.1 mg GAE/g. High TPC values were also obtained by Mac–EtOH and Mac–Hx fractions, 83±3 mg GAE/g and 93±5 mg GAE/g, respectively. In the SC-CO_2 there was a trend to increase the TPC with pressure. The lowest TPC value was observed at 100 bar and 50 ˚C (0.18±0.07 mg GAE/g), while the highest TPCs were obtained at 300 bar for all temperatures and at 200 bar and 40 ˚C (31±2 mg GAE/g) [51].

The oils extracted with solvents in the study by Wu et al. [53] resulted in low phenolic contents (3.829-4.1593 mg GAE/g). Although the polarities of chloroform and ethyl ether were stronger, hexane provided the higher extraction efficiency than other solvents. Rutin was the predominant phenolic compound in the oil extracted with hexane accounting for 76.65 g/100 g of the total amount.

Table 6. Bioactive compounds present in peach kernel oil

Method	Tocopherols (mg/kg oil)				Sterols (%)			Carotenoids (mg/ 100 g oil)	Reference
	α	β	γ	δ	β-sitosterol	Campesterol	D5-avenasterol		
SC-CO_2	/	/	44	/	ND	ND	ND	ND	[52]
SC-CO_2	ND	ND	ND	ND	1220 mg/kg seed	ND	ND	ND	[54]
SE	175.4-187.5	ND	110.2-126.7	74.5-85.9	78.83-80.01	4.13-4.39	8.90-12.18	ND	[56]
SE	37.3	ND	1.6	ND	ND	ND	ND	ND	[57]

EXTRACTION OF OILS FROM OLIVE KERNELS

The Olive (*Olea europaea* L.) is a small tree, which belongs to the family *Oleaceae* and is native to tropical and warm temperate regions of the world. The tree, famous for its fruit, is commercially important in the Mediterranean region as a prime source of olive oil [61]. Olive oil is widely used for food preparations and as a result of olive processing, a huge quantity of olive by-products are produced. The olive stone and seed are important by-products generated in the olive oil extraction, the whole olive stone is a rich source of bioactive compounds. These potentially valuable compounds are nuzhenide-oleoside, nuzhenide, salidroside, which are detected only in the olive seed; verbascoside only appears in significant quantities in the seed and pulp [62].

Alves et al. [63] extracted lipids from olive seeds at two ripeness stages (green and ripe). In both olive seeds, the predominant FA are C18:1 (56%), C18:2 (17%), and C16:0 (18%). In total lipid extract, ripeness caused a shift in the FA profile promoting an increase of 5.46% in C18:1 and a decrease in the rest of FA, except for C16:1 whose relative abundance was the same in both stages.

Lipids extraction using chloroform:methanol (2:1) from olive seeds [64] resulted in oil rich in oleic

(59.9%) and linoleic acid (16.3%) followed by palmitic acid (15.5%). The total lipids obtained in this study were 74.2±5.6.

Ranalli et al. [65] extracted lipids from seeds of seven olive varieties grown in Italy. The extraction was performed on Soxhlet apparatus using petroleum ether as solvent. The oil extracted had high content of unsaturated FA (85.38%) and unsaturated FA (13.53%).

Table 7. Extraction of oil from olive kernels

Extraction yield (%)	Method used for extraction	Fatty acid composition (%)							Location	Ref.
		C18:1	C18:2	C18:3	C16:1	C16:0	C18:0	C20:0		
ND	Mac Ripe	59.07 ±1.68	17.15 ±0.42	0.10 ±0.05	ND	16.04 ±0.64	6.81 ±1.04	0.33 ±0.11	Portugal	[63]
	Green	53.61 ±0.97	17.25 ±0.38	0.12 ±0.02	ND	17.61 ±1.43	10.22 ±0.69	0.45 ±0.11		
74.2 ±5.6	SE	59.9	16.3	0.1	ND	15.5	7.5	ND	Portugal	[64]
ND	SE	68.02 ±6.37	16.55 ±1.84	0.42 ±0.04	0.39 ±0.04	10.15 ±1.02	2.87 ±0.24	0.51 ±0.05	Italy	[65]

APPLICATION OF FRUIT KERNEL OILS

Oils derived from edible vegetables, fruits, seeds, tree and ground nuts have been safely consumed by, and applied to the skin of humans for thousands of years.

COSMETICS

Dermal toxicity of sour cherry kernel oil was tested on guinea-pigs for 21 days which resulted in none of the tested animals to exhibit adverse changes to the skin suggestive of an allergic or otherwise toxic reaction to contact with oil. The protection against UV damage had shown that creams containing this kernel oil at a dosage of 3% or greater provided significant protection [66].

Cosmetics companies report SCKO as it helps to reduce the signs of fine lines and wrinkles. It moisturizes the skin and can be used for hair and nail care as well [67], [68].

Apricot kernel oil (0.005%) resulted in not a dermal irritant or sensitizer when applied neat in a scalp/hair wax conditioner tested in total of 104 people [69].

A test was conducted in which participated 108 people by applying 19.749% apricot kernel oil in a face serum in this case eczema and erythema were observed [70]. Same results had appeared when 2.5% apricot kernel oil was applied in cream in which participated 119 people [71]. Although, in both these studies AKO was classified as not a primary irritant.

Interestingly, in a face cream (HRIPT-51) and eye cream (HRIPT-108) with 2% apricot kernel oil with 20 μL test material occluded it was shown that AKO is not a dermal irritant or sensitizer [72], [73]. The same was proven for a cream containing 1% apricot kernel oil applied neat on finn chmabers (HRIPT-57) [74].

Cosmetics companies report AKO as an extraordinarily versatile and skin-friendly base oil which is quickly absorbed and ideally suited for mature and sensitive skin, softens the skin and gives a radiant complexion [75], [76].

24% peach kernel oil in a lip balm was tested on 222 people with 0.2 g material occluded; 2 participants had low level, transient reactions during the induction, no other reactions were observed. This study concluded that test material was not a dermal sensitizer [77].

Cosmetic companies report PKO as oil with light texture that absorbs quickly without leaving a sticky film. It protects sensitive, dry, and mature skin and can help to strengthen the skin's immune system. Peach kernel oil smooths and hydrates the skin, improves skin elasticity and leaves a soft and supple feel [78], [79].

PHARMACEUTICALS

A microemulsion of sour cherry kernel oil was orally administered to mice at doses of 2.5%, 5%, and 10% for 10 days. In this case there was not toxicity evidence of this product in the dose range used in foods or healthcare, but also it improved the cardiac function recovery of the tested animals [80].

SCKO was tested for its antimicrobial activity in a study conducted by Kazempour-Samak et al. [81] in

which it was shown that it inhibited the growth of all microbial species tested especially Gram-positive strains. The most sensitive microorganism (lowest MIC) among the studied microorganisms was *Listeria monocytogenes*.

SCKO loaded gum Arabic and Maltodextrin microcapsules developed by spray-drying technique displayed antimicrobial activity against all pathogenic bacteria tested except *Escheria coli* when evaluated by agar well-diffusion assay, while the greatest antimicrobial activity was observed against *Pseudomonas aeruginosa* [82].

SCKO nanoemulsion was tested for cytotoxic impacts and apoptotic activity, anti-tumour effect by Maragheh et al. [83]. The results indicated the 36.5 nm stable SCKO-NE significantly decreased the breast cancer line MCF7 cells viability comparing with normal Human foreskin fibroblasts (HFF) cells and reduced the tumor size.

Nano-emulsions and nano-emulgels containg 2% statins and 8% apricot kernel oil were formulated and tested as alternative delivery system of statins [84]. Membrane release studies indicated that statins were released at higher flux values in nano-emulsions compared to their respective nano-emulgels. *Ex vivo* (skin diffusion) studies indicated higher median values in the nano-emulgels compared to their nano-emulsion counterparts.

In a rat model of chemically induced (trinitrobenzene sulfonic acid) ulcerative colitis, Minaiyan et al. [85] have used apricot extract and extract/oil and compared it with a standard treatment (prednisolone). The authors reported that both, on the macroscopic and microscopic levels, showed a significant improvement in disease activity.

Apricot kernel oil protects rat gastric mucosa against ethanol induced injury [86]. Group of albino rats treated AKO+ethanol exhibited significantly fewer gastric lesions compared to the ethanol group.

NUTRACEUTICALS

Apricot kernel oil (1.0%) was incorporated in chitosan films used for package of spiced beef by Wang et al. [87]. The results of this study indicated that CS films with AKO had better sensory attributes including taste, color, texture and overall acceptance during the whole storage period. Also, it was shown that it can display antimicrobial effects against *Listeria monocytogenes*.

AKO decreased markedly the cell line viability and migration of carcinoma of the tongue HNO97. Apricot oil caused no significant inhibition of normal oral epithelial cells viability in low doses. Shalash et al. [88] proved that AKO can be used as nutraceuticals in the treatment of oral cancer.

The effects of dietary apricot kernel oil (AKO) were evaluated in a rat model of cyclophosphamide-induced immunosuppression in the research of Tian et al. [89]. Rats had intraperitoneal injection with cyclophosphamide to induce immunosuppression and were then infused with AKO or normal saline (NS) for 4 weeks. Compared to the normal saline-treated group, lymphocytes isolated from rats administered AKO showed significant improvement in immunoglobulin IgA, IgM, IgG, interleukin (IL)-2, IL-12, and tumor necrosis factor-α (TNF-α) and reduced oxidative stress in rats treated with AKO. Dietary AKO positively affected rat growth and inhibited cyclophosphamide-associated organ degeneration. Thus, the use of AKO as a nutritional supplement can be proposed to ameliorate chemotherapy-associated immunesuppression.

Hao et al. [90] showed that peach kernel oil could reduce total cholesterol, triglyceride, low-density lipoprotein cholesterol levels, elevate the high-density lipoprotein cholesterol level in serum, and reduce the area of the aortic atherosclerotic lesions in high-fat diet fed Apolipoprotein E knockout mice. Moreover, peach kernel oil treatment resulted in significantly down regulate the expression of TF protein to inhibit the formation of atherosclerotic plaque. This study proves peach kernel oil may be a potential health food to prevent atherosclerosis in cardiovascular diseases.

CONCLUSION

In this review were highlighted the most prevalent data regarding extraction of oil from kernels of sour cherry, apricot, peach and olive and the different method used. Fatty acid composition and the presence of bioactive constituents in the oils was analyzed. A lot of research groups reported oil extraction from sour cherry, apricot and peach and only a few publications were available for olive kernels. All the authors report that these oils are very rich in poly unsaturated fatty acids, the predominant oleic acid followed by linoleic acid which makes them very attractive for their appliance in various industries. Many bioactive constituents were identified and quantified as tocopherols, tocotrienols, phytosterols, carotenoids and phenolic compounds.

Both *in vitro* and *in vivo* studies of sour cherry, apricot and peach kernel oil showed that they possess antioxidant, anti-microbial, apoptotic and anti-tumor activities. Clinical trials on humans of cosmetics containing these oils show that they are not a dermal irritant or sensitizer.

ABBREVIATIONS

ND-no data
C18:1-oleic acid
C18:2-linoleic acid
C18:3-linolenic acid
C16:1-palmitoleic acid
C16:0-palmitic acid
C18:0-stearic acid
C20:0-arachidic acid
SE- Soxhlet extraction
CP- cold press
SCKO-sour cherry kernel oil
GAE-gallic acid equivalent
GA-gallic acid
AKO-apricot kernel oil
DCM-dichloromethane
EtAC-ethyl acetate
EtOH-ethanol
HD-hydro distillation
Mac-maceration
HX-hexane
TPC-total phenolic compound
PKO-peach kernel oil
HRIPT-Human Repeat Insult Patch Test
MIC-minimum inhibitory concetration
CS-chitosan

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