Seed Biology

REVIEW

Open Access

https://doi.org/10.48130/seedbio-0024-0006

Seed Biology **2024**, 3: e008

Research progress of woody oil crops in China: a review

Jing Sun, Dongxu Huang, Shiyu Xia, Yuman Zhang and Jun Tao*

Jiangsu Key Laboratory of Crop Genetics and Physiology, College of Horticulture and Landscape Architecture, Yangzhou University, Yangzhou 225009, China

* Corresponding author, E-mail: taojun@yzu.edu.cn

Abstract

As a significant agricultural resource, woody oil crops have made remarkable progress in cultivation and utilization in China. This paper introduces several common woody oil crops in China, including high-quality oil species such as oil tea camellia (*Camellia oleifera*), walnut (*Juglans regia*), olive (*Olea europaea*), etc. The ecological adaptability, cultivation scale, and yield of these woody oil crops are discussed. Furthermore, the research on oil components in woody oil crops, including fatty acid analysis and other constituents, is summarized. Additionally, the methods for extracting oils and the latest advancements in woody oil crop research in China are described while also mentioning their potential applications in energy, chemical, and food industries. Finally, it highlights some current challenges and issues within the field of research while proposing future development directions. This review offers a comprehensive overview of woody oil crops research in China and serves as a valuable reference for researchers working within related fields.

Citation: Sun J, Huang D, Xia S, Zhang Y, Tao J. 2024. Research progress of woody oil crops in China: a review. *Seed Biology* 3: e008 https://doi.org/10.48130/seedbio-0024-0006

Introduction

Oilseed crops are of great importance to humans, both as a source of food and as raw materials for industrial production[1]. Generally, edible oils are derived mainly from the seeds of herbs, such as soybeans, rapeseed, sunflower seeds, peanuts, and others. Woody oil crops also play a crucial role in oilseed crops, with some being a preferred choice in people's daily diets. Furthermore, special nutrients can be obtained from woody oils that can help improve nutrient intake. The main woody oil crops currently produced globally include oil palm, olive tree, oil-tea camellia, and coconut tree. Different from herbaceous oil crops, woody oil crops have several characteristics, such as high yield, being perennial, not requiring continuous cultivation, and having high added value.

More than 3 billion people, particularly in Southeast Asia, consume edible oils as a primary dietary ingredient, palm oil finds extensive applications in industries, energy, healthcare, and various other fields. Remarkably, oil palm exhibits high oil production per unit, enabling it to yield approximately 81 million tons of oil each year from roughly 19 million hectares of land. In comparison, herbaceous oil crops such as soybeans necessitate larger areas of arable land. Amid the emerging challenges posed by phenological changes, pests, and diseases, comprehensive research on oil palm has delved deeper. Numerous innovative breeding and management techniques, including the development of high-yielding varieties, enhancements in oil composition, bolstered disease resistance, and climate resilience, have all contributed to more impressive and abundant oil palm yields[2].

Olive oil, extracted from the olive tree (*Olea europeae*), is famous for its health benefits and unique flavor[3]. However, due to their preference for Mediterranean climates, olive trees are not well-suited for cultivation in China. While there are regions in China where olive trees have been successfully planted, such as Sichuan Province and Gansu Province, the olive fruit yield and oil output remain low.

Coconut oil, on the other hand, is derived from the coconut (*Cocos nucifera*), with an oil yield of over 60%[4]. It is completely edible and has been consumed in tropical countries for thousands of years[5]. The fatty acids present in coconut oil are primarily medium-chain fatty acids, which the human body can easily digest and absorb, making it especially beneficial for those who are obese or have diabetes. Additionally, coconut oil has antibacterial and antioxidant properties, as well as the ability to improve physical immunity and prevent atherosclerosis[6].

However, coconut trees are mostly grown in Hainan Province in China, which lacks the conditions necessary for large-scale cultivation. Instead, the most suitable and largest woody oil crop in China is the *Camellia oleifera*. Oil-tea camellia is one of the four largest woody oil crops worldwide and is native to East Asia. Its seeds can be pressed to extract high-quality oil that is economically important for oil production and cosmetics[7]. Although there are many widely cultivated woody oil crops in the world, there are other species that are more suited to woody oil crops cultivation in China.

Distribution of woody oil crops and development in China

In 2022, China's consumption of edible oil reached 37.580 million tons. Conversely, domestic production yielded approximately 13.503 million tons of edible vegetable oil, with rapeseed oil accounting for the largest share at 4.93 million tons, followed by peanut oil at 3.22 million tons, corn oil at 1.05 million tons, and cottonseed oil at 1.105 million tons—an unprecedented increase compared to the previous year. Imports of oils and fats declined while achieving a self-sufficiency rate that rose by an impressive 6.9% from last year to reach 35.9%[8]. Despite this positive trend towards self-reliance, the significant reliance on imports remains a destabilizing factor that raises concerns about China's edible oil supply chain security. Consequently, one potential solution lies in the development and utilization of woody oil crops suitable for China's climate without encroaching upon additional arable land. Currently, China's industrialization of woody oil crops is primarily focused on the cultivation and promotion of oil tea camellia, walnut, olive, and tree peony. According to the statistics from the China Forestry and Grassland Administration, in 2020, the woody oil crop cultivation area in the country reached approximately 16.4 million hactares, yielding around 1.04 million tons of edible oil annually. The production of woody edible oil accounted for 8.5% of the total domestic edible oil output.

Woody oil crops play a crucial role in China's forest resources and offer numerous advantages over herbaceous oil plants. Firstly, China boasts a diverse range of woody oil crop species that thrive under various climatic conditions. Secondly, harnessing the potential of superior varieties can optimize the oil production capacity of woody oil crops by eliminating low-yielding strains. Moreover, the cultivation of woody oil crops is not limited to arable land and can be successfully carried out in mountainous environments. Due to China's vast territory, complex terrain, and diverse climate, there exists a wide range of woody oil crops. This paper primarily focuses on several significant woody oil crops that possess substantial planting areas and development potential (as shown in Fig.1 & Table 1).

Oil tea camellia (*Camellia oleifera*) is a small evergreen tree cultivated across more than 3,800,000 hectares in southern China[23]. It thrives in subtropical monsoon climates and is responsible for approximately 90% of woody plant oil production. Oil tea camellia is primarily found in the high mountains and hilly regions of central, eastern, and southern China, with significant production in Zhejiang, Jiangxi, Henan, Hunan, and Guangxi provinces[9].

Walnut (*Juglans regia*) is a deciduous tree that favors sunny environments and exhibits cold and drought tolerance. It thrives in fertile and humid sandy soils but does not have strict water and fertilizer requirements. Walnut is distributed throughout the plains and hilly regions of northern, northwestern, and southwestern China[11].

Olive (*Olea europaea*) is also deciduous and highly resistant to cold temperatures. It requires loose and porous planting soils, although soil quality requirements are not stringent. The primary distribution of olive in China includes Shaanxi, Sichuan, and Gansu provinces[13].

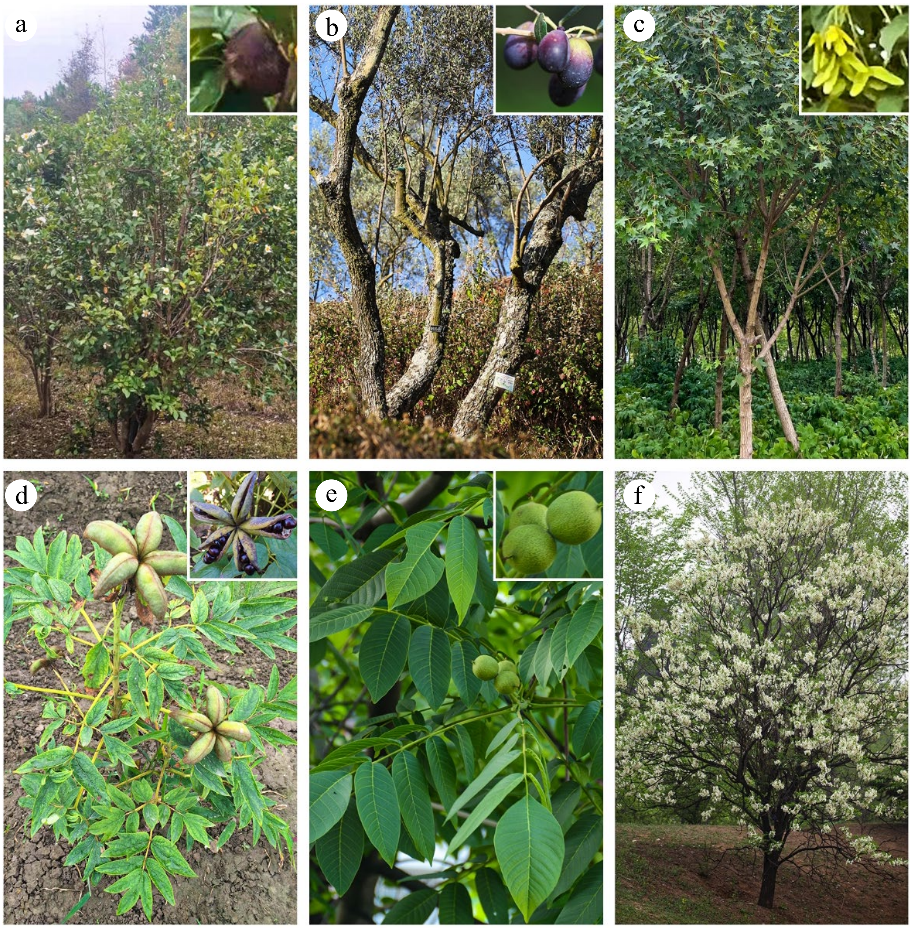

Fig. 1 Six woody oil crops planted mainly in China. (a) *Camellia oleifera* (photographed by Xiaoying Nie and Hua Li from Hezhou Academy of Agricultural Sciences). (b) *Olea europaea* (photographed by Shunli Yu from Institute of Botany, the Chinese Academy of Sciences). (c) *Acer truncatum* (photographed by Jing Sun from Yangzhou University). (d) *Paeonia ostii* (photographed by Jing Sun from Yangzhou University). (e) *Juglans regia* (photographed by Mei Tian from Institute of Botany, Chinese Academy of Sciences). (f) *Xanthoceras sorbifolium* (photographed by Shunli Yu from Institute of Botany, the Chinese Academy of Sciences).

Table 1. Distribution of the main woody oil crops in China.

Plant	Latin name	Distribution range in China	Area (thousand hectares)	Oil production (tons)	Oil content of seeds	Data source
Oil tea camellia	*Camellia oleifera*	Alpine and hilly areas in the subtropical region of southern China[9]	4,530 (by 2021)	–	50%[10]	www.forestry.gov.cn/main/28/20210329/162217154840445.html
Walnut	*Juglans regia*	Plains and hilly areas of north, northwest and southwest of China[11]	8,000 (by 2021)	33,000 (by 2021)	60%–65%[12]	www.chinaoil.org.cn/news/6660.html
Olive	*Olea europaea*	Shaanxi, Sichuan, and Gansu provinces[13]	90 (by 2021)	13,000 (by 2021)	25%[14]	www.chinaoil.org.cn/news/6660.html
Tree peony	*Paeonia ostii*	Shandong, Henan, Shanxi, and Shaanxi provinces[15]	129.3 (by 2021)	53,000 (by 2021)	24%–38%[16]	www.chinaoil.org.cn/news/6660.html
Shiny-leaved yellowhorn	*Xanthoceras sorbifolia*	Northwest, north and northeast of China[17]	175.3 (by 2019)	–	50%[18]	www.chinaoils.cn/news/15474.html
Purpleblow maple	*Acer truncatum*	Mainly concentrated in the north of China[19]	106.7 (by 2018)	–	38%[20]	www.gov.cn/xinwen/2018-11/02/content_5336947.htm
Hazelnut	*Corylus heterophylla*	Northeast and north of China[21]	1,333.3 (by 2021)	137,000 (by 2021)	59%[22]	www.chinaoil.org.cn/news/6660.html

Tree peony (*Paeonia ostii*) are deciduous shrubs that require ample sunlight and thrive in loose, porous, and well-drained sandy loam soils. It can be predominantly found in Shandong, Henan, Shanxi, and Shaanxi provinces in China[15].

Shiny-leaved yellowhorn (*Xanthoceras sorbifolia*) is widely cultivated in the northwest, north, and northeast regions of China. It serves as a prominent woody energy resource plant and has been utilized for biodiesel production over a long period of time[17]. Shiny-leaved yellowhorn is highly adaptable and can grow in various environments, including barren and salt-alkali lands, sandy lands, abandoned lands, stony mountainous areas, and loess hilly lands[24].

Purpleblow maple (*Acer truncatum*) is considered a promising species as a raw material to produce nervonic acid[25]. It is distributed in the north regions of the Yangtze River in China, mainly concentrated in the north and southeast. *Acer truncatum* cannot withstand high-temperature exposure and exhibits slow growth[19].

Hazelnut (*Corylus heterophylla*) is an essential nut crop in China. As a deciduous shrub, it thrives in light and humid climates and exhibits strong cold resistance[26]. Hazelnut can be cultivated in sandy loam soil, clay soil, and saline-alkali soil, showcasing considerable adaptability. Its primary distribution is in the northeast and north of China[21].

Fatty acid composition of woody oils in China

The fatty acids found in woody oils consist mainly of saturated and unsaturated fatty acids. Except for a few woody oils like coconut oil and palm oil, unsaturated fatty acids are the predominant component. The variations in fatty acid composition, content, metabolic pathways, and regulatory mechanisms in different types of woody oils contribute to their diverse applications in fields such as food, medicine, energy, and industry. Additionally, in woody oil crops with a wide distribution, the oil composition of the same plant can vary due to factors like climate and soil conditions. This variability adds to the significant development potential of woody oils. The following discussion provides a detailed exploration of the abundance of both saturated and unsaturated fatty acids (as shown in Table 2).

Saturated fatty acids

Saturated fatty acids are characterized by the absence of carbon-carbon double bonds in their carbon chains, making their structures relatively stable. In woody oils, saturated fatty acids are typically present as stearic acid and palmitic acid. They are found in higher amounts in plants such as palm oil and cocoa butter. For instance, the palmitic acid content in palm oil ranges from 41.3%–46.3%[27], while the stearic acid content in cocoa butter can reach up to 36.0%[28]. It is worth noting that excessive consumption of saturated fatty acids may lead to obesity, elevated triglyceride, and LDL cholesterol levels, as well as an increased risk of coronary heart disease. Therefore, it is recommended to consume them in moderation as part of a well-balanced diet.

Unsaturated fatty acid

Unsaturated fatty acids are a type of fatty acid that contains carbon-carbon double bonds in their carbon chains. They are typically categorized into two groups based on the number of carbon-carbon double bonds present in their structure: monounsaturated fatty acids and polyunsaturated fatty acids. Monounsaturated fatty acids include oleic acid, which is found in higher amounts in oil-tea camellia seed oil, olive oil, and almond oil. Specifically, its content can reach up to 76.0%–81.4%[29], 66.0%–72.0%[30] and 57.0%–71.0%[31], respectively. Oleic acid has been shown to have beneficial effects on health, such as lowering blood sugar levels, regulating blood lipids and reducing cholesterol levels.

Polyunsaturated fatty acids are fatty acids that cannot be synthesized by the human body, and they are also necessary substances for human physiological activities. They can be further classified into two main types, omega-3 and omega-6, based on the position of their farthest carbon-carbon double bond in the carboxyl group. Omega-3 has the effect of relieving and inhibiting inflammation, and omega-6 promotes the development of inflammation, the interaction of the two can regulate the stability of blood pressure and inflammation in the body and maintain a relative balance. The Food and Agriculture Organization of the United Nations recommends that the ratio of omega-6 to omega-3 in the diet should be 4:1 to 10:1 and that more than 10:1 should increase the intake of omega-3. Alpha-linolenic acid represents omega-3, while linoleic acid represents omega-6. Chinese woody oils are particularly rich in

Table 2. Fatty acid composition in some woody oils.

Plant oils (Latin name)	Palmitic acid (C16:0) (%)	Stearic acid (C18:0) (%)	Oleic acid (C18:1) (%)	Linoleic acid (C18:2) (%)	Linolenic acid (C18:3) (%)	Data source
Oil-tea camellia seed oil (*Camellia oleifera*)	3.9%–14.5%	0.3%–4.8%	68.0%–87%	3.8%–14%	1.4% or less	GB/T 11765-2018
Olive oil (*Olea europaea*)	7.5%–20.0%	0.5%–5.0%	55.0%–83.0%	2.5%–21.0%	1.0% or less	GB/T 23347-2021
Palm oil (*Elaeis guineensis*)	39.3%–47.5%	3.5%–6.0%	36.0%–44.0%	9.0%–12.0%	0.5% or less	GB/T 15680-2009
Walnut oil (*Juglans regia*)	2.2%–10.0%	0.5%–6.0%	11.5%–35.0%	50.0%–70.0%	5.5%–18.0%	GB/T 22327-2019
Almond oil (*Prunus armeniaca*)	3.0%–8.1%	3.5% or less	40.8%–80.8%	12.0%–50.5%	3.0% or less	GB/T 41386-2022
Tree peony seed oil (*Paeonia ostii*)	–	–	21.0% or higher	25.0% or higher	38.0% or higher	GB/T 40622-2021
Shiny-leaved yellowhorn oil (*Xanthoceras sorbifolium*)	4.5%–6.0%	1.6%–2.4%	27.5%–33.5%	41.1%–46.8%	6.0%–7.0%	LS/T 3265-2019
Maple seed oil (*Acer truncatum*)	–	–	15.0%–30.0%	30.0%–40.0%	–	GB/T 37748-2019
Flaxseed oil (*Linum usitatissimum*)	3.7%–7.9%	2.0%–7.0%	9.5%–30.0%	10.0%–20.0%	45.0%–70.0%	GB/T 8235-2019
Rapeseed oil (*Linum usitatissimum*)	1.5%–6.0%	–	8.0%–65.0%	9.5%–30.0%	5.0%–13.0%	GB/T 1536-2021
Sunflower seed oil (*Helianthus annuus*)	5.0%–7.6%	2.7%–6.5%	14.0%–39.4%	48.3%–74.0%	0.3% or less	GB/T 10464-2017
Cottonseed oil (*Gossypium hirsutum*)	19.0%–26.4%	1.5%–3.3%	13.5%–21.7%	46.7%–62.2%	0.7% or less	GB/T 1537-2019
Peanut oil (*Arachis hypogaea*)	8.0%–14.0%	1.0%–4.5%	35.0%–69.0%	13.0%–43.0%	0.3% or less	GB/T 1534-2017
Maize oil (*Zea mays*)	8.6%–16.5%	3.3% or less	20.0%–42.2%	34.0%–65.6%	2.0% or less	GB/T 19111-2017
Sesame seed oil (*Sesamum indicum*)	7.9%–12.0%	4.5%–6.9%	34.4%–45.5%	36.9%–47.9%	–	GB/T 8233-2018
Soya bean oil (*Glycine max*)	8.0%–13.5%	2.0%–5.4%	17.0%–30.0%	48.0%–59.0%	4.2%–11.0%	GB/T 1535-2017

omega-3, with sacha inchi oil and tree peony seed oil having a content of 48.4%[32] and 41.4%[33], respectively.

With the increased research in this area in recent years, some emerging woody oils have gradually entered people's vision. Tree peony seed oil, sacha inchi oil, and other oils have gained people's favor by their low ratio. They not only enrich the types of edible oils to increase people's choices but also meet people's growing pursuit of healthy life, making contributions to China's food security. These oils have potential applications in various medical fields, such as promoting cardiovascular health, relieving joint pain and discomfort, enhancing concentration and reducing stress, eliminating migraines, rejuvenating skin, lowering blood sugar, and preventing diabetes. Conversely, omega-6 is found widely in walnut oil, shiny-leaved yellowhorn oil, and maple seed oil, with respective contents of 51.2%–69.0%[34], 37.1%–46.2%[35], and 32.4%[36]. These types of oils have been shown to help regulate hormone levels, relieve skin allergies and eczema, maintain skin health and reduce levels of harmful cholesterol.

Additional ingredients in woody oils

In addition to the dominant fatty acids, woody oils are a rich source of beneficial compounds that promote human health. These non-triacylglycerol substances, collectively identified as fat concomitants, encompass polyphenol compounds, plant sterols, squalene, tocopherols, and other compounds. The concentration and composition of these fat concomitants differ across various woody oils, thereby conferring unique nutritional and research significance to each type of woody oil.

Phenolic compounds

Phenolic compounds are composed of multiple hydroxyl groups attached to a benzene ring, exhibiting diverse structures and being broadly categorized into flavonoids, stilbenes, phenolic acids, and lignans. While the majority of phenols are soluble in water, some possess lipophilic properties and many exist as glycosides complexed with sugars. In woody oil, the presence of polyphenols enhances its oxidation stability, prolongs storage duration, and improves sensory attributes such as color and flavor[37]. Moreover, due to distinctive biological activities, phenolic compounds demonstrate antioxidative effects, anti-inflammatory properties, inhibition of cancer cell proliferation, reduction in blood lipid levels, regulation of intestinal flora, enhancement of mitochondrial function, and prevention of metabolic syndrome. Consequently, phenolic compounds have found extensive applications in medicine food industry cosmetics[38,39].

Oil-tea camellia seed oil has a total phenol content ranging from 99.1 to 138.0 mg/kg[40,41]. A total of 22 phenolic compounds were identified in the oil-tea camellia seed oil, including one coumarin compound, 11 derivatives of phenolic acid, and ten derivatives of flavonoids[42].

Chinese-produced olive oil was found to contain mostly iridoid polyphenols, with a total phenol content ranging from 25.1 to 793.0 GAE mg/kg. The results of a generalized linear model indicated that variety difference is the most significant factor influencing the content of characteristic bioactive substances in olive oil[43].

Walnut oil from three different regions of southwest, northwest, and east China exhibited a total phenol content ranging from 345.0 to 2,579.0 mg/kg, and the total phenol content is a major determinant of the oxidation stability of walnut oil[44].

Eleven varieties of almonds from Xinjiang, China were chosen for the study. The cold-pressed almond oil had a total phenolic content of 322.0–1,151.0 mg/kg, while the hot-pressed almond oil contained 478.0–1,040.0 mg/kg of total phenols. The linear relationship between the DPPH clearance, reducing power, and total phenol content was not significant, suggesting that polyphenolic substances are important antioxidants in almond oil but not the sole contributors[45].

Tree peony seed oil contains various phenolic substances, including catechin, chlorogenic acid, epicatechin, rutin, and kaempferol[46]. Mao et al. identified nine varieties of peony seeds and reported that the content of resveratrol could reach up to 212 mg/kg. The most significant bioactive ingredient in tree peony seed is paeoniflorin with a content of up to 2,366 mg/kg[47]. Paeoniflorin exhibits antispasmodic, analgesic, sedative effects as well as memory improvement properties. Moreover, it has physiological benefits such as anti-free radical damage and inhibition of intracellular calcium overload and anti-KA neurotoxicity[48].

Phytosterols

Phytosterols consist of cyclopentane perhydro phenanthrene and possess alcohol groups. They are widely distributed in plant cell membranes, either in a free form or in conjunction with fatty acids and sugars. Woody oils can detect the presence of phytosterols, and distinct sterol structures display varying biological activities. In recent years, phytosterols have garnered significant attention due to their discovered potential in reducing blood cholesterol levels, preventing cardiovascular diseases, exerting anti-inflammatory, antibacterial, and antioxidant effects[49−52]. Furthermore, research has indicated that conjugated sterols demonstrate enhanced solubility with oil and consequently exhibit superior cholesterol-lowering efficacy[53].

The results revealed the presence of a total of nine sterols in oil-tea camellia seed oil, with concentrations ranging from 3,072.9 to 5,713.5 mg/kg. Both bound and free forms of sterols were detected, with the bound ones accounting for 97.4% −99.4% of the total amount. The major sterols identified included lanosterol, β-amyrin, β-sitosterol, among others[54].

Upon analyzing sterols in six monovarietal Tunisian virgin olive oils, it was found that β-sitosterol and Δ5-avenasterol were the predominant sterols in all samples. The content of campesterol and stigmasterol was relatively lower. Notably, there was a significant difference observed among olive oil varieties, with the total sterol content ranging from 1,172.6 to 2,320.4 mg/kg[55].

The walnut oil content in different regions of China ranged from 540.0 to 1,594.0 mg/kg. Walnut oil exhibited higher levels of campesterol, Δ5-avenasterol, and β-sitosterols, collectively accounting for over 90% of the total plant sterol content. Trace amounts of stigmasterol, Δ5,24-stigmastadienol, and Δ7-campesterol were also detected in Chinese walnut oil[44].

Almond oil possessed a total sterol content ranging from 1,796.0 to 4,554.0 mg/kg[56], with β-sitosterol, Δ5-avenasterol, and campesterol being the major components[57].

The phytosterol content in tree peony seed oil was quantified at 1,973.4 mg/kg[58], with the analysis of unsaponifiable compounds conducted using gas chromatography-mass spectrometry (GC-MS), revealing sitosterol and fucosterol as the predominant sterols[59].

The total amount of sterols in shiny-leaved yellowhorn oil ranged from 913.9 to 1,661.5 mg/kg. Stigmasterol (577.5–1,060.7 mg/kg) and sitosterol (253.9–421.0 mg/kg) were the main components, while small amounts of campesterol (8.4–52.2 mg/kg) and sitostanol (73.1−175.5 mg/kg) were also detected[60].

Maple seed oil contained four phytosterols, including stigmasterol, campesterol, campestanol, and sitosterol. Sitosterol was the predominant phytosterol, and the highest total phytosterol content (950.3 mg/kg) was found in virgin oil[61].

Squalene

Squalene, an acyclic triterpene composed of six isoprene, is abundant in nature. It possesses various benefits including enhanced oxygen transport capacity in cells, promotion of blood circulation, liver protection and treatment, and enhancement of immunity[62,63]. It is particularly suitable for patients with mental depression, brain fatigue, liver damage, and altitude hypoxia.

In a study conducted by Zhang et al., the content of squalene in oil-tea camellia seed oil was determined to be 153.8 mg/kg using gas chromatography[64]. This method is rapid, reproducible, and sensitive, making it suitable for squalene determination in woody oil. Another similar method revealed a higher squalene content of approximately 0.6% (6,359.9 mg/kg) in olive oil, as reported by Wu et al.[65]. Walnut oil, on the other hand, contained a lower amount of squalene, measuring at 31.4 mg/kg according to Jin et al.[66]. Gas chromatography-mass spectrometry analysis conducted by Luoin et al. showed that seven kinds of almond oil had squalene content ranging from 261.0 to 364.0 mg/kg[67]. Tree peony seed oil, however, exhibited no significant advantage in terms of squalene content, with levels ranging from 28.6 to 62.7 mg/kg as reported by Zhang et al.[68].

Tocopherol

The tocopherol content in woody oils were significantly higher than that in herbal oils. Tocopherol is the hydrolyzed product of vitamin E, which exists in four forms: α, β, γ, and δ. It is a natural antioxidant. Within the appropriate range, tocopherol can increase the antioxidant effect of cells, regulate reproductive function, and improve skin quality[69]. It also has certain anti-aging effects, promotes lipid metabolism, prevents arteriosclerosis, and reduces blood lipids[70].

In oil-tea camellia seed oil, the content of α-tocopherol is between 240.0 and 410.0 mg/kg. β-, γ-, and δ-tocopherol are present but in lower quantities than the detection rang[71].

The main tocopherol in olive oil is α-tocopherol, with a content range of 126.2 to 292.8 mg/kg. β- and δ-tocopherol are less than 10.0 mg/kg, while γ-tocopherol is between 8.9 and 42.5 mg/kg[72].

Three forms of tocopherol (α, γ, and δ) were detected in walnut oil from China. The content of α-tocopherol is low, with an average value of 46.3 mg/kg. γ-tocopherol and δ-tocopherol have higher contents, with average values of 316.6 and 309.3 mg/kg, respectively. Tocopherol is also one of the main factors affecting the oxidation stability of walnut oil[44].

In two different experimental orchards in Spain and Morocco, the contents of different tocopherols in the almond oil of 17 almond varieties were determined. The results showed that the content of α-tocopherol was the highest, ranging from 210.9 to 553.4 mg/kg. The second highest was γ-tocopherol, with a content range of 4.6 to 14.9 mg/kg. The δ-tocopherol content ranged from 0.2 to 1.0 mg/kg[73].

The total amount of tocopherol in tree peony seed oil was 563.0 mg/kg, with γ-tocopherol being the dominant form at 484.2 mg/kg. α-tocopherol and δ-tocopherol were present in lesser amounts. Tree peony seed oil has weak oxidation stability, making it prone to oxidation and not suitable for long-term storage[74].

In shiny-leaved yellowhorn oil, the total amount of tocopherol is 483.2 mg/kg. It includes α-tocopherol (75.5 mg/kg), β-tocopherol (6.5 mg/kg), γ-tocopherol (344.4 mg/kg), and δ-tocopherol (56.8 mg/kg)[75].

The tocopherol content in maple seed oil is 1,252.3 mg/kg, mainly consisting of (β+γ)-tocopherol and δ-tocopherol, with quantities of 728.6 and 375.8 mg/kg, respectively[76].

Other components

In addition to the four substances mentioned earlier, there are numerous other components present in woody oils. Maple seed oil contains a high level of nervonic acid, exceeding

5.8%[77], and shiny-leaved yellowhorn oil exhibited a nervonic acid content of 2.2%[78], which has been found to have anti-aging effects on the human brain. Nervonic acid is a specialized fatty acid that is abundant in nerve and brain tissues. It serves as an essential component of the biofilm and plays a crucial role in brain functions such as thinking, memory, commanding, and information transmission.

Palm oil, on the other hand, contains a significant amount of carotenoids, with a content range of 500.0−700.0 mg/kg[27]. The main components of these carotenoids are β-carotene and α-carotene. Carotenoids are known for their ability to protect the visual system, maintain healthy skin tissue, and provide resistance against adverse environmental conditions. However, it is important to note that the body cannot produce carotenoids on its own and must obtain them through external sources. These diverse fatty acids collectively contribute to the rich flavor profile and nutritional value of woody oil, making it an area of extensive research and development.

Woody oil extraction technology

Mechanical pressing

There are various techniques available for the extraction of woody oils, including mechanical pressing, solvent extraction, supercritical fluid extraction, and so on. The mechanical press method is widely employed as an effective means of obtaining oil by exerting pressure on plant seeds or fruits using specialized equipment. This extraction is characterized by its simplicity and suitability for a wide range of woody plants. Depending on whether the oil seeds or fruits are heated before pressing, mechanical pressing can be categorized as either cold pressing or hot pressing.

Cold-pressed oil is characterized by its clarity, transparency, light color, and delicate flavor. The entire pressing process omits steaming or stir-frying pretreatment, ensuring that the oil temperature remains below 60 °C. This method effectively preserves bioactive compounds such as vitamin E, squalene, polyphenols, and sterols. Moreover, cold-pressing oil exhibits superior physical and chemical properties when compared to high-temperature hot pressing methods. However, it is worth noting that the cold-pressing process requires a longer processing time and results in lower production efficiency and oil yield[79].

The experiment demonstrated that the oil-tea camellia seeds attained optimal oil content by cold pressing when fully matured, with an oil yield of 29.4% achieved by harvesting the seeds 7 d after frost and storing them at temperatures ranging from 0−7 °C for a duration of 1 to 2 months[80]. The extraction process of tree peony seed oil under cold pressing was optimized based on the response surface experiment design. The maximum oil yield of 23.1% and a residual oil rate of 7.0% were achieved under the following conditions: pressure of 4.6 MPa, feed rate of 1,600 g/min, pressing temperature of 73 °C, and water content of 4.6%[81]. Shiny-leaved yellowhorn oil was obtained through mechanical pressing at ambient temperature. The findings indicated that, when subjected to a pressure of 55 ± 2 MPa and pressed for 6-8 h, the kernel-to-shell ratio of 9:1 (g : g) resulted in an oil yield of 40.4%. Furthermore, the mass fraction of linoleic acid and oleic acid was found to be higher compared to other extraction methods[82].

Hot pressing is a method of extracting oil from seeds or fruits by crushing, baking at high temperatures, and pressing. This technique disrupts plant cells and reduces the viscosity of the oil, resulting in a higher yield compared to cold pressing. The resulting hot-pressed oil has a darker color and a strong aroma. However, steaming at high temperatures can lead to varying degrees of loss in unsaturated fatty acids and active ingredients. In oil-tea camellia seed soil obtained through hot pressing, 65 different compounds were detected, with heterocyclic compounds and aldehydes accounting for 67.52% of the total volatile components[83]. This observation may be attributed to a complex Maillard reaction between carbohydrates and proteins that occurs during the high-temperature roasting of oil-tea camellia seeds[84]. Additionally, under high temperature conditions with oxygen present, hazardous substances such as benzo (α) pyrene can be produced[85]. Furthermore, elevated temperatures are also an important factor contributing to the formation of trans fatty acids in cooking oils[86].

Solvent extraction

Solvent extraction is a widely employed industrial oil extraction technology worldwide[87], wherein organic solvents are utilized to dissolve the oil present in plant material, followed by solvent removal through evaporation or distillation processes. This method offers advantages such as high oil yield, short processing time, and relatively low production cost due to minimal oil residue content. However, it is crucial to address potential issues associated with residual solvents[88].

Solvent-extracted oil No. 6, n-hexane, trichloromethane, ether, petroleum ether, ethanol and acetone are commonly utilized solvents for oil extraction through leaching extraction[87]. The experiment on extracting residual oil from the defatted cake of oil-tea camellia seeds revealed that, under the conditions of 95% ethanol volume, a liquid-solid ratio of 10: 1 (mL : g), a temperature of 92 °C, a duration of 3 h, and two extraction cycles, the average yield of residual oil in the defatted cake of oil-tea camellia seeds reached an impressive 96.0%. Notably, the use of 95% ethanol as a solvent offers several advantages: it is readily available, and easy to recover and reuse without causing pollution or leaving any solvent residue behind. Consequently, this method holds great promise for further development in oil extraction[89].

Cao et al. utilized seven solvents to evaluate the oil yield, lipid composition, fat concomitants, and antioxidant capacity of tree peony seed oil. It was observed that n-hexane and isopropyl alcohol exhibited the highest oil yield at 35.6%. Notably, tree peony seed oil extracted from isopropyl alcohol demonstrated significantly elevated phenolic compounds, thereby exhibiting superior antioxidant capability[90].

Lv & Ma optimized the extraction conditions of shiny-leaved yellowhorn oil by employing cyclohexane as the extraction solvent and conducting an orthogonal test based on a single-factor test. The optimal extraction parameters were determined as follows: a liquid-solid ratio of 4:1, a leaching time of 3 h, and a leaching temperature of 70 °C. Under these specified conditions, the oil yield of shiny-leaved yellowhorn oil can reach up to 30.0%[91]. The low oil yield may be attributed to the absence of multiple extraction reflux and variations in extractants.

Supercritical fluid extraction

Supercritical fluid extraction is an advanced technology for extracting woody oils efficiently and rapidly by utilizing changes in solvent temperature and pressure to achieve a supercritical state. This technique offers several advantages, including a simple process, short extraction time, high efficiency, absence of residual solvents, maximum preservation of natural active compounds, selective separation, as well as the production of impurity-free oil with excellent color and high purity. Carbon dioxide (CO_2), being a non-polar and non-toxic extractant that is readily available at low cost due to its critical temperature (31.3 °C) and critical pressure (7.15 MPa), is particularly suitable for extracting non-polar unsaturated fatty acids from woody oils[33]. However, it should be noted that the associated equipment for this technology can be relatively expensive and not yet widely accessible[92].

The optimal extraction conditions for oil-tea camellia seed oil were as follows: an extraction pressure of 33 MPa, an extraction temperature of 43 °C, and an extraction time of 2 h. Under these specific conditions, the extraction yield reached 39.6%, accounting for 95.4% of the total oil. Supercritical carbon dioxide extraction not only exhibits exceptional efficiency in extracting oil-tea camellia seed oil but also effectively preserves its natural aroma and flavor derived from tea seeds, ensuring the protection of tocopherol content[93].

Optimization of the supercritical carbon dioxide extraction process for tree peony seed oil was conducted using a mixed-variable design method. The optimal process conditions are characterized by an extraction temperature of 45 °C, an extraction pressure of 32 MPa, a separation temperature of 35 °C, a separation pressure of 11.5 MPa, an extraction time of 2.8 h, and a raw material loading amount of 187 g. Under these conditions, the yield of tree peony seed oil reached a maximum of 19.5%. Furthermore, the analysis revealed that tree peony seed oil contains 92.3% total unsaturated fatty acids, with linolenic acid being the most abundant[33]. The tree peony seed oil was extracted using supercritical carbon dioxide extraction a light color, transparency, and clarity. It possessed a higher concentration of unsaturated fatty acids, lower saponification value, and peroxide value. The quality of the oil surpassed that obtained through other extraction methods[92].

Wang et al. employed a supercritical carbon dioxide extraction technique to obtain shiny-leaved yellowhorn oil. They discovered that by applying an extraction pressure of 30 MPa, maintaining an extraction temperature of 50 °C, utilizing an oxygen flow rate of 40 L/h, and conducting the extraction process for 150 min, they were able to achieve an oil yield as high as 44.6%. Furthermore, the total content of unsaturated fatty acids in the extracted oil was determined to be 82.2%[94]. The application of supercritical carbon dioxide extraction for edible oil also serves to mitigate the decline in the quality of oil products resulting from the hydrolytic rancidity of free fatty acids, which are prone to oxidation[95].

In addition to the aforementioned three commonly used methods for extracting woody oils, there are also water extraction, water enzyme extraction, and other techniques available. Water extraction is a traditional method of oil recovery that utilizes the hydrophilic and non-oily components of proteins found in oil seeds or fruits, taking advantage of the differing densities between oil and water. This method is particularly suitable for soft oilseeds or high-oil-content fruits as it ensures the preservation of nutritional value and flavor in the obtained oil. Water enzyme extraction has been developed based on water extraction by incorporating protease, amylase, and pectinase enzymes to disrupt plant cell walls and facilitate the release of oil from cells. Currently, these methods are still in the research stage due to their low oil yield and high production costs.

The pretreatment of oil seeds or fruits before oil extraction can significantly increase the oil yield and enrich the nutritive properties of the extracted oil. Herein, various techniques for effective pretreatment are introduced.

Steam explosion assisted extraction

Steam explosion-assisted extraction is a process that involves the swift release of steam molecules that penetrate plant tissues and apply mechanical force to oil seeds or fruits. This conversion of steam's internal energy to mechanical energy allows for more efficient decomposition of raw materials and disruption of cell structure, resulting in accelerated oil extraction. At a pressure of 1.6 MPa and a processing time of 30 s, oil-tea camellia seeds achieved the highest oil yield, accounting for 86.56% of the total oil content, exhibiting a significant increase of 1.27 times compared to untreated samples. This treatment also led to elevated levels of polyphenols, squalene, and tocopherol, resulting in improved physical and chemical properties as well as enhanced antioxidant activity[96]. Additionally, the blasting process induced Maillard reactions that further enhanced the flavor profile of the oil.

Ultrasonic-assisted extraction

The process of ultrasonic-assisted extraction involves using ultrasound waves to create strong and rapid cavitation effects and agitation. This disrupts the cellular structure of oil seeds or fruits, allowing solvents to penetrate the cells more effectively and improve the efficiency of oil extraction. In the extraction of oil-tea camellia seed oil, ethanol was used as the extraction reagent. The optimum extraction conditions were determined through single-factor and orthogonal tests. These conditions included an 80% volume fraction of ethanol, a solid-liquid ratio of 1:14 (g : mL), an ultrasonic temperature of 80 °C, an ultrasonic time of 100 min, and an ultrasonic power of 310 W. Under these optimized conditions, the yield of oil-tea camellia seed oil reached 39.7%[97].

Optimization of the extraction process of tree peony seed oil using petroleum ether as solvent and ultrasonic-assisted method was conducted by Lin et al. Under the conditions of extraction time of 45 min, extraction temperature at 45 °C, extraction power of 90 W, and a liquid-solid ratio of 7:1, the maximum oil yield was achieved at 33.9%[98]. Ultrasonic-assisted extraction of woody oils is known for its non-destructive effect on the oil composition, ease of operation, and control over conditions. This study offers valuable insights for the extraction and development of woody oils.

Microwave-assisted extraction

The process of microwave-assisted extraction involves using heat to separate oil from cells in oil seeds or fruits and transfer it into an extraction solvent, resulting in faster, more efficient, and higher-quality extractions compared to conventional methods.

Tree peony seed oil was extracted using an ultrasonic microwave extractor. Single factor tests revealed that crude oil yield reached 31.5% when n-hexane was used as the extraction solvent, with a solid-liquid ratio of 1:8 (g : mL), and initial irradiation at 600 W for 8 min at 40 °C followed by ultrasonic oscillation at 560 W for 20 min. Compared to other extraction methods, this approach can be conducted under ambient temperature and pressure conditions, resulting in reduced extraction time and enhanced yield[99]. Shiny-leaved yellowhorn oil was extracted using petroleum ether as a solvent under microwave-assisted treatment. The optimal conditions were as follows: a liquid-solid ratio of 16:1 (ml : g), an extraction time of 20 min, an extraction temperature of 85 °C, and a microwave power setting of 100 w. After four repeated extractions, the oil yield reached 53.3%[82], which was significantly higher compared to that obtained through conventional solvent extraction. The use of microwave-assisted extraction for woody oils offers streamlined operation, rapid extraction rates, and minimal environmental impact.

In conclusion, diverse extraction methods apply to various woody oil crops and specific requirements, enabling researchers to select the appropriate method based on practical circumstances for obtaining woody oils. Simultaneously, it is imperative to prioritize the safety and environmental sustainability of the extraction process to ensure the quality and long-term development of the oil.

Discussion on future development trends

Since the 21st century, woody oils germplasm resources have become an essential source of high-quality edible oils. Protecting these resources has become imperative to effectively address national grain and oil strategic security issues. Germplasm resource protection can be divided into external and internal factors, the latter includes plant internal components and genes. The external factors limit the establishment of new woody oil crop plantations to areas with low ecological value to reduce their negative ecological impacts and maintain the habitat quality of farmland ecology[100]. The internal factors: protect germplasm resources by manipulating plant internal components, such as lignin, in crops such as oil palm to reduce the loss of germplasm resources due to white rot[101]. In addition, genetic factors, such as the CgICUT1 enzyme genes, can be modified to protect camellia from carbon gangrene bacteria and preserve germplasm resources[102].

It is known that there are various types of woody oil crops in China, and a significant number of untapped wild plant resources are hidden in the mountains. China has a vast territory with diverse terrains and ecological environments, and numerous wild and unknown oil germplasm resources are distributed under different habitat conditions. Unfortunately, these resources are not protected as no one collects and utilizes them, resulting in resource loss. Therefore, the protection and development of oil germplasm resources are crucial as they are interconnected and mutually influential.

China's abundant ecological resources offer favorable conditions for the development of woody oils germplasm resources. Firstly, we need to improve exploration technology to unlock the potential of germplasm resources. Secondly, enhancing oil crop cultivation techniques, such as *Camellia oleifera*, to simplify variety development, improve pollination efficiency, and obtain high-yield seeds. Thirdly, we should expand and streamline the collection and sales channels of oil resources.

It is also important to focus on the entire production chain of woody oil crops, increase economic income, and improve the high development and protection of woody oils to bring added value. Before industrial processing, these woody oil crops have ornamental value as green species. For instance, oil palm, olive, coconut, and other species with appreciable leaves, as well as *Camellia oleifolia* and other plants with appreciable flowers, can be used for small-scale greening. However, the high flaking rate of fruits and seeds in many varieties of paulownia restricts its commercial planting. Nevertheless, there is limited research on this issue currently, and resolving this problem is a primary strategy to enhance the utilization rate and value of paulownia.

In recent years, with the advancement of science and technology, there has been a significant development and utilization of woody oils, which have become increasingly integrated into various aspects of human life. These woody oils not only serve as a valuable source of high-quality edible vegetable oil but also exhibit diverse functionalities in cosmetics, healthcare, industry, energy, and other domains.

Oil-tea camellia seed oil is extensively employed in cosmetic production due to its ability to regulate skin's water-oil balance, enhance skin resistance against aging effects, and facilitate the treatment, repair, and regeneration of severely scalded skin. Furthermore, oil-tea camellia seed oil can be utilized as a healthcare product with notable benefits such as preventing cardiovascular diseases, regulating body immunity levels detoxifying properties with anti-inflammatory effects, and promoting gastrointestinal regulation[103].

In the field of cosmetics, tree peony seed oil, rich in unsaturated fatty acids, exhibits properties that promote skin metabolism, enhance cuticle softness, and improve skin moisture retention. Its physical and chemical characteristics comply with the industry standards for cosmetic base oils and find applications in essence formulations, masks, makeup creams, and other related products[104]. Research indicates that tree peony seed oil possesses specific effects on the skin such as sun protection, UV resistance, repair capabilities, and whitening properties. Consequently, it can be utilized for developing corresponding sunscreen products[105]. Furthermore, owing to its omega-3 richness as a vegetable oil product developed through microencapsulation technology[106], tree peony seed oil also holds promising prospects within the health care product industry.

Walnut oil can be transformed into powdered form to cater to the diverse processing requirements of various food industries, exhibiting excellent stability and potential for substituting milk fat and a portion of milk protein. Additionally, walnut oil can be processed into soft gel capsules as a convenient ready-to-consume food product that is easily portable. Furthermore, the incorporation of walnut oil in fat milk injections offers benefits such as blood sugar reduction and provision of energy for human consumption, thereby playing a significant role in the medical domain[107].

In addition to its corresponding healthcare effects, shiny-leaved yellowhorn oil has also found extensive applications in the field of renewable energy. Shiny-leaved yellowhorn does not occupy arable land and exhibits strong environmental adaptability, resulting in high yields. The physicochemical properties of its seed kernel oil meet the quality requirements for biodiesel, making it an ideal substitute for diesel fuel[108]. Furthermore, the advanced lubricating oil derived from shiny-leaved yellowhorn oil is biodegradable and does not cause significant environmental pollution, thus representing an environmentally friendly alternative. Additionally, due to its high protein utilization rate, strong emulsification capabilities, low freezing point (−37 °C), and excellent stability after emulsification, shiny-leaved yellowhorn oil is frequently employed as a raw material in various daily necessities such as paint production, soap manufacturing, hair wax formulation, skin care products development, it can also be utilized as food additives[109].

The richness of fatty acids and vitamin E in maple seed oil renders it a suitable facial cleanser and moisturizer, enhancing the skin's antioxidant capacity and regulating its permeability[110]. Research has demonstrated that maple seed oil exhibits inhibitory effects on tumor cell growth and promotes the regeneration of damaged nerve cells[111], with particular interest directed towards nervonic acid by numerous researchers.

Additionally, other woody oils play a significant role. Palm oil and coconut oil not only serve as primary sources of dietary fat but also possess medicinal properties for treating various ailments. Palm oil can be directly incorporated into diverse food processing procedures, exhibiting the potential to prevent night blindness, regulate blood lipids, and mitigate the risk of cancer and other chronic diseases. Coconut oil aids in preventing cardiovascular disease and combating infectious illnesses[112].

Author contributions

The authors confirm contribution to the paper as follows: study conception and design: Tao J, Sun J, Huang DX; data collection: Sun J, Huang DX, Xia SY, Zhang YM; analysis and interpretation of results: Sun J, Huang DX; draft manuscript preparation: Sun J, Huang DX, Xia SY, Zhang YM. All authors reviewed the results and approved the final version of the manuscript.

Data availability

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

Acknowledgments

This work was supported by grants from Forestry Science and Technology Promotion Demonstration Fund Project of Central Finance, Su [2023]TG05. Jiangsu Modern Agriculture Industry Technology System project, JATS[2023]446, JATS[2023] 041.

Conflict of interest

The authors declare that they have no conflict of interest.

Dates

Received 24 November 2023; Accepted 18 March 2024; Published online 20 May 2024

References

1. García-González DL, Aparicio-Ruiz R, Aparicio R. 2008. Virgin olive oil-Chemical implications on quality and health. *European Journal of Lipid Science and Technology* 110(7):602−7
2. Murphy DJ, Goggin K, Paterson RRM. 2021. Oil palm in the 2020s and beyond: challenges and solutions. *CABI Agriculture and Bioscience* 2(1):1−22
3. Kaftan A, Elmaci Y. 2011. Aroma characterization of virgin olive oil from two Turkish olive varieties by SPME/GC/MS. *International Journal of Food Properties* 14(5):1160−69
4. Wu LH, Bai XP, Zhang YZ, Liu J, Li YM, et al. 2016. Vacuum microwave-ultrasound-assisted enzymatic extraction of virgin coconut oil. *China Oils and Fats* 41(8):5−10
5. Deen A, Visvanathan R, Wickramarachchi D, Marikkar N, Nammi S, et al. 2021. Chemical composition and health benefits of coconut oil: an overview. *Journal of the Science of Food and Agriculture* 101(6):2182−93
6. Kardinasari E, Devriany A. 2020. Phytochemical identification of bangka origin virgin green coconut oil: Anti-inflammatory and anti-bacterial potential. *Enfermería Clínica* 30:171−74
7. Su MH, Shih MC, Lin KH. 2014. Chemical composition of seed oils in native Taiwanese *Camellia* species. *Food Chemistry* 156:369−73
8. Wang RW. 2023. Production, marketing, import and export of grain and oil in China in 2022. *China Oils and Fats* 48(6):1−7
9. Yang Q, Tang J, Zhou GY. 2021. Characterization of *Diaporthe* species on *Camellia oleifera* in Hunan Province, with descriptions of two new species. *Mycokeys* 84:15−33
10. Xia EH, Jiang JJ, Huang H, Zhang LP, Zhang HB, et al. 2014. Transcriptome analysis of the oil-rich tea plant, *Camellia oleifera*, reveals candidate genes related to lipid metabolism. *PLoS ONE* 9(8):e104150
11. Chen H, Chen H, Hu L, Wang L, Wang S, et al. 2017. Genetic diversity and a population structure analysis of accessions in the Chinese cowpea [*Vigna unguiculata* (L.) Walp.] germplasm collection. *The Crop Journals* 4(2):363−72
12. Calvo P, Lozano M, Espinosa-Mansilla A, González-Gómez D. 2012. *In-vitro* evaluation of the availability of ϖ-3 and ϖ-6 fatty acids and tocopherols from microencapsulated walnut oil. *Food research international* 48(1):316−21
13. Xu Y, Huang L, Li JH, Deng Y, Zhang JG, et al. 2022. Identification and genetic diversity analysis of olive cultivars in Longnan based on phenotype and SSR markers. *Forest Research* 35(4):33−43
14. Wang CZ, Chen Q, Luo JJ, Bai XY, Wang Y, et al. 2013. Development and Industrial Prospect of China's Olive. *Biomass Chemical Engineering* 47(2):41−46
15. Sun J, Guo H, Liu M, Chen M, Zhu M, et al. 2022. Histology and transcriptomic profiling reveal the dynamics of seed coat and endosperm formation in tree peony (*Paeonia ostii*). *Horticulture Research* 9:uhac106
16. Han J, Liu Z, Li X, Li J, Hu Y. 2016. Diversity in seed oil content and fatty acid composition in three tree peony species with potential as sources of omega-3 fatty acids. *The Journal of Horticultural Science and Biotechnology* 91(2):175−79
17. Wang MK, Meng NT, Bi QX, Liu XJ, Yu HY, et al. 2021. Evaluation of drought tolerance based on stomatal characters and selection of germplasm resources from *Xanthoceras sorbifolia*. *Bulletin of Botanical Research* 41(6):957−64
18. Zhang S, Zu YG, Fu YJ, Luo M, Liu W, et al. 2010. Supercritical carbon dioxide extraction of seed oil from yellow horn (*Xanthoceras sorbifolia* Bunge.) and its anti-oxidant activity. *Bioresource technology* 101(7):2537−44
19. Guo X, Wang R, Chang R, Liang X, Wang C, et al. 2014. Effects of nitrogen addition on growth and photosynthetic characteristics of Acer truncatum seedlings. *Dendrobiology* 72:151−61
20. Wang XY, Fan JS, Wang SQ. 2006. Development situation and outlook of nervonic acid plants in China. *China Oils and Fats* 31(3): 69−71
21. Ruiz del Castillo ML, Gómez Caballero E, Blanch GP, Herraiz Maballero E. 2002. Enantiomeric composition of filbertone in hazelnuts and hazelnut oils from different geographical origins. *Journal of the American Oil Chemists Society* 79(6):589−92
22. Geng PF, Liu JW, Hu CR, Liu LY, He DP. 2018. Comparison of three extraction method of hazelnut oil and optimization of its supercritical CO_2 extraction process. *China Oils and Fats* 43(5):7−10+15

23. Li, L, Yang Q, Li H. 2021. Morphology, phylogeny, and pathogenicity of pestalotioid species on *Camellia oleifera* in China. *Journal of Fungi* 7(12):1080
24. Shen Z, Zhang K, Ma L, Duan J, Ao Y. 2017. Analysis of the genetic relationships and diversity among 11 populations of *Xanthoceras sorbifolia* using phenotypic and microsatellite marker data. *Electronic Journal of Biotechnology* 26:33−39
25. Fan Y, Lin F, Zhang R, Wang M, Gu R, et al. 2022. *Acer truncatum* Bunge: A comprehensive review on ethnobotany, phytochemistry and pharmacology. *Journal of Ethnopharmacology* 282:114572
26. Şahİn S, Tonkaz T, Yarilgaç T. 2022. Chemical composition, antioxidant capacity and total phenolic content of hazelnuts grown in different countries. *Journal of Tekirdag Agriculture Faculty-Tekirdag Ziraat Fakultesi Dergisi* 19(2):262−70
27. Wang H, Song F, Cao FY, Chen WJ, Zhao SL. 2014. Analysis of nutrition and functional composition in palm oil. *Chinese Journal of Tropical Agriculture* 34(6):71−74
28. Tu XH, Du LQ, Wei F, Lv X, Huang FH, et al. 2019. A review on seven tropical woody oil crops in China. *Chinese Journal of Tropical Agriculture* 39(4):114−22
29. Zhang H, Gao P, Mao Y, Dong J, Zhong W, et al. 2023. Physicochemical study of *Camellia oleifera* Abel. seed oils produced using different pretreatment and processing methods. *LWT* 173: 114396
30. Ferro MD, Cabrita MJ, Herrera JM, Duarte MF. 2023. A new laboratory scale olive oil extraction method with comparative characterization of phenolic and fatty acid composition. *Foods* 12(2):380
31. Ouzir M, Bernoussi SE, Tabyaoui M, Taghzouti K. 2021. Almond oil: A comprehensive review of chemical composition, extraction methods, preservation conditions, potential health benefits, and safety. *Comprehensive Reviews in Food Science and Food Safety* 20(4):3344−87
32. Penagos-Calvete D, Duque V, Marimon C, Parra DM, Restrepo-Arango SK, et al. 2019. Glycerolipid composition and advanced physicochemical considerations of sacha inchi oil toward cosmetic products formulation. *Cosmetics* 6(4):70
33. Zhao JJ, Tian G, Jiang TY, Lei MD, Sun KW, et al. 2021. Supercritical CO_2 fluid extraction of peony seed oil. *Journal of the Chinese Cereals and Oils Association* 36(01):131−135+154
34. Gao P, Jin J, Liu R, Jin Q, Wang X. 2018. Chemical compositions of walnut (*Juglans regia* L.) oils from different cultivated regions in China. *Journal of the American Oil Chemists' Society* 95(7):825−834
35. Chang YM, Zhang CH, Liu YC. 2009. Study on the fatty acid composition of the seed oil of *Xanthoceras sorbiflia* and its property. *Shanxi Forestry Science and Technology* 38(3):37−39
36. Qiao Q, Xue W, Feng Z. 2018. Variability of seed oil content, fatty acid composition, and nervonic acid content in *Acer truncatum*, native to 14 regions of China. *Grasas y Aceites* 69(4):e274
37. Zeb A. 2021. A comprehensive review on different classes of polyphenolic compounds present in edible oils. *Food Research International* 143:110312
38. Wang D, Wang T, Zhang Z, Li Z, Guo Y, et al. 2022. Recent advances in the effects of dietary polyphenols on inflammation in vivo: Potential molecular mechanisms, receptor targets, safety issues, and uses of nanodelivery system and polyphenol polymers. *Current Opinion in Food Science* 48:100921
39. Li JK, Meng YH, Liu L, Wang XY, Wang XL, et al. 2021. Utilization of food industry by-products in China. *Journal of Food Science and Technology* 39(6):1−13
40. Liu GY, Li ST, Liang L, Zhu WQ, Zhou WL, et al. 2022. Effect of phenolic compounds in different forms extracted from oil-tea camellia seed oil on oil oxidative stability. *China Oil and Fats* 47(2): 85−90+117
41. Wei Z, Yang KZ, Luan X, Li XJ, Duan ZQ, et al. 2021. Optimization of free characteristic phenolic and total phenol from *Camellia oleifera* seed oils by response surface methodology. *Journal of the Chinese Cereals and Oils Association* 36(11):116−22
42. Liu G, Zhu W, Li S, Zhou W, Zhang H, et al. 2022. Antioxidant capacity and interaction of endogenous phenolic compounds from tea seed oil. *Food Chemistry* 376:131940
43. Yu L. 2022. *Characterization, antioxidant properties, and discrimination of Chinese olive oils*. Thesis. Jiangnan University, China. pp. 36−54.
44. Zhou ZT, Gao P, Zhang JZ, He DP. 2020. Chemical composition and oxidation stability index of walnut oils from different production regions in China. *Science and Technology of Cereals, Oils and Foods* 28(1):17−22
45. Wang Y, Zhou B, Zhong HY. 2014. Content of phenol and antioxidant ability of apricot kernel oil under different pretreatment. *Food and Machinery* 30(6):149−52
46. Han XY. 2016. *Analysis of fatty acid and other functional components in tree peony seed oil*. Thesis. Northwest Agriculture & Forestry University, China. pp. 13−29.
47. Mao YY, Han JG, Tian F, Tang X, Hu YH, et al. 2017. Chemical composition analysis, sensory, and feasibility study of tree peony seed. *Journal of Food Science* 82(2):553−61
48. Li MQ, Wu Y, Sun Q, Chen J, Wang F, et al. 2012. Research progress of Peony Seed. *Natural Product Research and Development* 24(S1):182−84
49. Cheung CL, Ho DKC, Sing CW, Tsoi MF, Cheng VKF, et al. 2017. Randomized controlled trial of the effect of phytosterols-enriched low-fat milk on lipid profile in Chinese. *Scientific reports* 7(1):41084
50. Hu Q, Zhuo Z, Fang S, Zhang Y, Jie F. 2017. Phytosterols improve immunity and exert anti-inflammatory activity in weaned piglets. *Journal of the Science of Food and Agriculture* 97(12):4103−4109
51. Pierre Luhata L, Usuki T. 2021. Antibacterial activity of β-sitosterol isolated from the leaves of *Odontonema strictum* (*Acanthaceae*). *Bioorganic & Medicinal Chemistry Letters* 48:128248
52. Liu R, Xu Y, Chang M, Tang L, Lu M, et al. 2021. Antioxidant interaction of α-tocopherol, γ-oryzanol and phytosterol in rice bran oil. *Food Chemistry* 343:128431
53. Garcia-Llatas G, Alegría A, Barberá R, Cilla A. 2021. Current methodologies for phytosterol analysis in foods. *Microchemical Journal* 168:106377
54. Jia WC, Fang EH, Wu YF, Xu DM, Wang XQ. 2021. Speciation analysis of phytosterols in camellia seed oil and their dynamic changes during refining and storage. *Food Science* 42(16):39−45
55. Krichène D, Allalout A, Salvador MD, Fregapane G, Zarrouk M. 2010. Fatty acids, volatiles, sterols and triterpenic alcohols of six monovarietal Tunisian virgin olive oils. *European journal of lipid science and technology* 112(3):400−9
56. Gao Y, Wang BK, Xue F, Guan YN, Chen DD. 2023. Advance on the extraction, nutritional composition and health benefit of almond oil. *Food and Machinery* 39(5):232−40
57. Wang W, Wang HL, Xiao XZ, Xu XQ. 2019. Chemical composition analysis of seed oil from five wild almond species in China as potential edible oil resource for the future. *South African Journal of Botany* 121:274−81
58. Fan YK, Xiang T, Wang W, Shen JF. 2018. Research progress on nutrients and processing technology of peony seed oil. *Food & Machinery* 34(10):196−201
59. Wang Y, Ji SJ, Mao WY, Wang SS, Cui T. 2012. Measurement of the non-saponifiable matters and octacosanol in peony seed oil and sunflower seed wax by gas chromatography-mass spectrometry (GC-MS) method. *Journal of Agricultural University of Hebei* 35(4): 104−7
60. Liu YL, Guo YY. 2020. Study on comprehensive quality of *Xanthoceras sorbifolia* Bunge oil from different producing areas and different processes. *Cereals and Oils* 33(6):1−6
61. Cheng M. 2021. Effects of refining process on the quality of *Acer truncatum* seed oil. *China Oils and Fats* 46(8):16−19
62. Farràs M, Almanza-Aguilera E, Hernáez Á, Agustí N, Julve J, et al. 2021. Beneficial effects of olive oil and Mediterranean diet on

cancer physiopathology and incidence. *Seminars in Cancer Biology* 73:178−95

63. Ibrahim NI, Fairus S, Zulfarina MS, Naina Mohamed I. 2020. The efficacy of squalene in cardiovascular disease risk-a systematic review. *Nutrients* 12(2):414
64. Zhang DS, Xue YL, Jin QZ, Wang XG, Zhang D, et al. 2013. Determination of squalene in oil-tea camellia seed oil. *China Oils and Fats* 38(11):85−88
65. Wu LH, Zhao JJ, Wu LM, Li G, Li ZK. 2021. Determination of squalene in vegetable oil by gas chromatography-mass spectrometry with rapid saponification-neutral alumina chromatographic purification. *China Oils and Fats* 46(10):132−36
66. Jin CA, Wang RC, Wang XY, Jin ML, Wang YF, et al. 2022. Comparison of 37 fatty acids and squalene in walnut oil and common vegetable oils. *Science and Technology of Food Industry* 43(12):261−67
67. Luo YH, Huang MG, Qiu JR, Li YJ. 2022. Determination of squalene in almond oil by water bath saponification combined with gas chromatography-mass spectrometry. *Guangdong Chemical Industry* 49(15):173−175+172
68. Zhang D, Xue YL, Duan ZQ, Li XJ, Zhu L, et al. 2017. Analysis and comparison of chemical composition in peony seed oil and flaxseed oil. *China Oils and Fats* 42(10):34−38
69. Wu LM, Zhao JJ, Cai JW, Wu LH, Zhang YH, et al. 2022. The types, contents and health function of fat concomitants in edible vegetable oils. *Journal of Henan University of Technology (Natural Science Edition)* 43(6):10−18+29
70. Liu YL, Peng TE, Ma YX. 2010. Determination of tocopherols and tocotrienols in rice bran oil and the by-product deodorizer distillate. *China Oils and Fats* 35(3):70−74
71. Wang LX, Luo F, Guo SH, Yao XH, Zhong HY. 2020. Effects of microwave and infrared radiation treatment of oil-tea camellia seeds on V_E content in pressed oil-tea camellia seed oil. *China Oils and Fats* 45(3):58−61
72. Zhang D, Xue YL, Zhu L, Xu R, Chai J. 2017. Olive and virgin olive oil quality analysis in China. *Journal of the Chinese Cereals and Oils Association* 32(2):88−93
73. Kodad O, Estopañán G, Juan T, Mamouni A, Company RSI. 2011. Tocopherol concentration in almond oil: Genetic variation and environmental effects under warm conditions. *Journal of Agricultural and Food Chemistry* 59(11):6137−41
74. Mao CX, Li GH, Li PX, Zhu P, Kang XM. 2014. Analysis of triglycerides composition structure and physicochemical properties of peony seed oil. *Modern Food Science and Technology* 30(4):142−46
75. Yang XQ, Xie XF, Meng XY, Ding B, Cheng S, et al. 2022. Analysis and comparison of nutritional composition and fatty acid composition between *Xanthoceras sorbifolia* oil and common edible oil. *Shandong Forestry Science and Technology* 52(2):42−46
76. Tong YX, Xu JM, Chen F, Yin ZX, Liu N, et al. 2022. Advance in chemical components and products application status of *Acer truncatum* Bunge. *China Oils and Fats* 47(2):118−23
77. Qiao Q, Wang X, Ren H, An K, Feng Z, et al. 2019. Oil content and nervonic acid content of *Acer truncatum* seeds from 14 regions in China. *Horticultural Plant Journal* 5(1):24−30
78. Tu XH, Wan JY, Xie Y, Wei F, Quek S, et al. 2020. Lipid analysis of three special nervonic acid resources in China. *Oil Crop Science* 5(4):180−86
79. Li ZG, Ma L, Chen YZ, Peng SF, Peng YH, et al. 2017. Cold-pressing technology of oil-tea Camellia. *Hunan Forestry Science & Technology* 44(4):92−95
80. He ZH, Zhan RC, Jiang SJ, Yu WL, Ding DG, et al. 2018. Study on key techniques for cold pressing pretreatment of Camellia oleifera seed and its application. *Journal of Zhejiang Agricultural Sciences* 59(5):728−30
81. Li WG, Sun XL, Zu YG, Zhao XH. 2020. Optimization peony seed oil extraction process at suitable temperature and physicochemical property analysis. *Bulletin of Botanical Research* 40(1):73−78
82. Deng H, Sun J, Fan XC, Wen HB. 2007. Comparison of different extraction technologies for seed oil of *Xanthoceras sorbifolia* Bunge. *Journal of Northeast Forestry University* 35(10):39−41
83. Ma L, Chen YZ, Zhong HY, Zhou B, Peng SF, et al. 2016. The effect of techniques on quality of oil-tea camellia seed oil. *Journal of Southwest Forestry University* 36(6):164−69
84. Yang M, Liu CS, Zhou Q, Zheng C, Huang FH. 2010. Processing effects on volatile flavor composition of rapeseed oil. *Chinese Journal of Oil Crop Sciences* 32(4):551−57
85. Qin YC, Liu BT, Xue JS, Wang LL, Yang L, et al. 2020. Study on quality difference of hot-pressed and cold-pressed camellia oil. *Journal of the Chinese Cereals and Oils Association* 35(5):97−104
86. Li CM, Zhang YB, Li S, Deng YY, Xu C, et al. 2015. Mechanism of formation of trans-fatty acids. *Journal of the Chinese Cereals and Oils Association* 30(7):141−46
87. Yang JY, Chen F, Song LW, Hu R, Deng ZY. 2016. Research progress on extraction technology of camellia oil. *Food and Machinery* 32(2):183−87
88. Guo X, Peng YX, Hu CR, He DP, Liu LY. 2017. Effects of different oil producing processes on characteristics and quality of *Xanthoceras sorbifolia* Bunge. oil. *China Oils and Fats* 42(9):8−13
89. Tang ZJ, Li Y, Dong XR, Zhou BL, Yang C. 2012. Study on extraction of residual oil in defatted cake of camellia using ethanol as solvent. *Chemistry & Bioengineering* 29(5):60−63
90. Cao WC, Wang YJ, Shehzad Q, Liu ZY, Zeng RJ. 2022. Effect of different solvents on the extraction of oil from peony seeds (*Paeonia suffruticosa* Andr.): Oil yield, fatty acids composition, minor components, and antioxidant capacity. *Journal of Oleo Science* 71(3):333−42
91. Lv SY, Ma TJ. 2023. Process optimization for the solvent extraction of *Xanthoceras sorbifolia* Bunge oil. *Journal of Beijing University of Agriculture* 38(01):97−101
92. Shi XF, Ren LM. 2016. Research advance on preparation of peony seed oil by supercritical carbon dioxide extraction. *Grain Processing* 41(6):47−54
93. Huang CL. 2012. *The Supercritical carbon dioxide extraction and functional quality evaluation of Camellia seed oil*. Thesis. Changsha University of Science and Technology, China. pp. 9−19.
94. Wang YL, Zhao WY, Liu SY, Wang Y. 2014. Supercritical extraction and fatty acid composition of seed oil in *Xanthoceras sorbifolia*. *Nonwood Forest Research* 32(1):135−39
95. Meng XH, Pan QY. 2009. Perspectives on oleochemical industry using supercritical carbon dioxide. *Food and Fermentation Industries* 35(10):113−18
96. Zhang S, Pan Y, Zheng L, Yang Y, Zheng X, et al. 2019. Application of steam explosion in oil extraction of camellia seed (*Camellia oleifera* Abel.) and evaluation of its physicochemical properties, fatty acid, and antioxidant activities. *Food Science and Nutrition* 7(3):1004−16
97. Liang ZH, Li HR, Zhu HY, Li P, Chen HX, et al. 2021. The technological condition of ultrasonic-assisted ethanol extraction of camellia seed oil. *The Food Industry* 42(9):1−4
98. Lin X, Yi X, Ni S. 2021. Optimization of ultrasonic-assisted extraction and fatty acid composition of oil from *Paeonia suffruticosa* Andr. seed. *Journal of Oleo Science* 70(1):39−49
99. He YY, Lv XX. 2021. Ultrasonic microwave synergistic extraction of peony seed oil. *The Food Industry* 42(8):102−5
100. Guerrero-Casado J, Carpio AJ, Tortosa FS, Villanueva AJ. 2021. Environmental challenges of intensive woody crops: The case of super high-density olive groves. *Science of the Total Environment* 798:149212
101. Paterson RRM, Moen S, Lima N. 2009. The feasibility of producing oil palm with altered lignin content to control *Ganoderma* disease. *Journal of Phytopathology* 157(11−12):649−56
102. Ye C, He Z, Peng J, Wang R, Wang X, et al. 2023. Genomic and genetic advances of oil tea-camellia (*Camellia oleifera*). *Frontiers in Plant Science* 14:1101766

103. Jiang X, Zhao JP, Liu P, Wang K, Xu JM, et al. 2022. Research progress of fatty acid composition, purification and application of woody oil. *Biomass Chemical Engineering* 56(2):60−68
104. Qiao SM, Wang Y, Wu P. 2023. Research progress of peony seed oil. *China Fruit & Vegetable* 43(2):24−29+50
105. Ma XY, Zhao YH, Liu HM. 2021. Progress in efficacy of natural vegetable oils in sunscreen cosmetics. *China Oils and Fats* 46(1):71−75
106. Zhang QH, Ma WJ, Liang XH, Xiao L, Cheng M. 2021. Optimization of formula and characterization of peony seed oil-fish oil microcapsules. *China Food Additives* 32(6):55−63
107. Shi P, Chang YM. 2015. Quality evaluation and comprehensive development and utilization of walnut oil. *Shanxi Forestry Science and Technology* 44(1):37−40
108. Jiang QD, Wang JG. 2011. Application field and development prospect of *Xanthoceras sorbifolia* Bunge. *Gansu Science and Technology* 27(15):134−35
109. Ao Y, Duan J, Yu HY, Jiang CY, Ma LY. 2012. Research progress on *Xanthoceras sorbifolia* Bunge. *Journal of China Agricultural University* 17(6):197−203
110. Wang XY. 2013. High quality raw material of cosmetics industry-*Acer truncatum* Bunge. seed oil. *China Oils and Fats* 38(7):5−7
111. Wang XY, Xie SJ, Wang GH. 2018. Application research status and prospect of *Acer truncatum* Bunge. seed oil rich in nervonic acid in China. *China Oils and Fats* 43(12):93−95+104
112. Boateng L, Ansong R, Owusu WB, Steiner-Asiedu M. 2016. Coconut oil and palm oil's role in nutrition, health and national development: A review. *Ghana Medical Journal* 50(3):189−96