Current Research in Food Science 8 (2024) 100753

Contents lists available at ScienceDirect

Current Research in Food Science

journal homepage: www.sciencedirect.com/journal/current-research-in-food-science

Review Article

A critical review of the bioactive ingredients and biological functions of *camellia oleifera* oil

Peiju Qin [a], Junjun Shen [a,b,*], Jeigen Wei [a], Yuqi Chen [a]

[a] Hunan Provincial Key Laboratory of Forestry Biotechnology & International, Cooperation Base of Science and Technology Innovation on Forest Resource, Biotechnology, Central South University of Forestry and Technology, Changsha, China

[b] Laboratory of Molecular Nutrition, National Engineering Research Center for Rice and Byproducts, Central South University of Forestry and Technology, Changsha, 410004, China

ARTICLE INFO

Handling Editor: Professor A.G. Marangoni

Keywords:
Camellia oleifera oil
Bioactive component
Extraction method
Biological functions

ABSTRACT

Camellia oleifera oil is a pure and natural high-grade oil prevalent in South China. *Camellia oleifera* oil is known for its richness in unsaturated fatty acids and high nutritional value. There is increasing evidence indicating that a diet rich in unsaturated fatty acids is beneficial to health. Despite the widespread production of *Camellia oleifera* oil and its bioactive components, reports on its nutritional components are scarce, especially regarding systematic reviews of extraction methods and biological functions. This review systematically summarized the latest research on the bioactive components and biological functions of *Camellia oleifera* oil reported over the past decade. In addition to unsaturated fatty acids, *Camellia oleifera* oil contains six main functional components contributing to its antioxidant, antibacterial, anti-inflammatory, antidiabetic, anticancer, neuroprotective, and cardiovascular protective properties. These functional components are vitamin E, saponins, polyphenols, sterols, squalene, and flavonoids. This paper reviewed the biological activity of *Camellia oleifera* oil and its extraction methods, laying a foundation for further development of its bioactive components.

1. Introduction

Camellia oleifera, a natural high-grade oil plant, is cultivated in the subtropical region of southern China and is one of the world's four major oil tree species. It belongs to the *Theaceae* and is also known as camellia, wild camellia, and white flower camellia (Fig. 1) (Xiao et al., 2020). *Camellia oleifera* oil, extracted from the seeds of the *Camellia oleifera* plant, is an edible vegetable oil renowned for its high medicinal and nutritional value (Wang et al., 2017b). Camellia fruit shells, a by-product of the *Camellia oleifera* industry, are a promising source of polysaccharides. (Zhou et al., 2021). Virgin *Camellia oleifera* oil is a natural product obtained directly by mechanical or physical methods without further refining.

Camellia oleifera oil contains several health-promoting compounds (Li et al., 2022). After the extraction process, a cake of *Camellia oleifera* seeds is left behind, containing a large number of proteins, polysaccharides, saponins, and other substances. (Tang et al., 2017). Enzymatic hydrolysis of the cake could result in functional peptides, which can potentially be used to develop functional foods. (Feng et al., 2021).

Camellia oleifera oil has been gaining increasing attention recently due to its high commercial, medicinal, cosmetic, and ornamental value. Its valuable gene pool also presents opportunities for developing new *Camellia oleifera* varieties. (Yang et al., 2022). China's *Camellia oleifera* oil processing industry primarily focuses on producing edible oil, a healthy alternative recommended by the Food and Agriculture Organization of the United Nations (Guo et al., 2023). As scientists develop a deeper functional understanding of the active ingredients in *Camellia oleifera* oil, such as sterols, fatty alcohols, tocopherols, triterpene alcohols, and squalene, there is potential for the development of high-value cosmetics and pharmaceutical products (Xiao et al., 2020). Research into extracting specific physiologically active substances like polyphenols, saponins, squalene possessing antioxidants and anti-inflammatory effects, and flavonoids with excellent anti-cancer effects from *Camellia oleifera* oil is ongoing (Zhou et al., 2019). Although studies have focused on one or more active components of *Camellia oleifera* oil, little attention has been given to the biological functions of the numerous functional components found in *Camellia oleifera* seeds.

This review aims to systematically summarize the active ingredients, physiological functions, and extraction methods of camellia oil,

* Corresponding author. 498 Shaoshan Road, Changsha, 410004, China.
E-mail addresses: shenjunjun@yeah.net, T20071400@csuft.edu.cn (J. Shen).

https://doi.org/10.1016/j.crfs.2024.100753
Received 13 January 2024; Received in revised form 18 April 2024; Accepted 24 April 2024
Available online 25 April 2024

A. *Camellia oleifera* **plant** **B.** *Camellia oleifera* **fruits**

Fig. 1. *Camellia oleifera* plant and fruits.

providing valuable insights into the development of high-value, nutritious *Camellia oleifera* oil or functional components extracted from the seeds for the production of high-value functional foods or adjuvant drugs. Exploring better performance and applications of camellia oil's active components presents a practical and significant study area for future research.

2. Distribution and characteristics

Camellia oleifera is predominantly found in Southeast Asia, extending from the Himalayas to Japan and southern China to Indonesia (Guo et al., 2018). The largest *Camellia oleifera* planting area is in China, where it is cultivated across 14 provinces around the Yangtze River Basin and the Jiangnan region, with significant concentrations in Hunan, Jiangxi, and Guangxi (Yang et al., 2016). While small numbers populations of these plants exist in Southeast Asi a, and Japan, as well as in the Philippines, India, Brazil, and South Korea, Hainan Camellia oleifera oil iscan only be extracted through simple physical processing due to its unique geographical environment(Wang et al., 2021). The kernel rate and oil content of *Camellia oleifera* oil vary among different varieties, production areas, and climates. In Guangxi provinces, such as Hechi, Baise, and Wuzhou, the kernel rate ranges from 53.29% to 68.91%, while the oil content varies from 47.05% to 59.51%. These factors also influence the fatty acid types and contents in Camellia oleifera seeds due to these factors (Chen et al., 2011).

Furthermore, an analysis of the fatty acid composition of four *Camellia oleifera* varieties from two producing areas in Zhejiang Province indicated revealed differences in the content of saturated fatty acids (SFAs), unsaturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids, rangingwhich ranged from 9.90% to 13.40%, 86.55%–90.10%, 73.50%–84.50% and 4.20%–13.05%, respectively. The study found that Zhejiang Hongshan *Camellia oleifera* oil had lower contents of palmitic acid and linoleic acid contents. In contrast, where as Jinhua *Camellia oleifera* oil extract had the highest level of oleic acid and with the lowest content of palmitic acid and linoleic acid. Although the main fatty acid contents are similar, the total fatty acid compositions differed notably among the four varieties (Cao et al., 2017).

In another study conducted in Guizhou Province, situated within a warm and humid subtropical monsoon climate area, *Camellia oleifera* demonstrated early fruiting, high yield, and strong disease resistance, with oil content ranging from 35.03% to 53.47%. The findings also showed that varieties were suitable for cultivation in Southwest China because of their higher oil content than the local *Camellia oleifera* varieties (Li et al., 2022; Liu et al., 2021). In Taiwan, the study of fatty acid components in 12 native *Camellia oleifera* species collected from different regions revealed significant differences in crude fat and individual fatty acid contents, potentially due to differences in. These differences were possibly due to geographical location. The content of a variety of *Camellia oleifera* oil, Ganzhouyou-1 in Ganzhou, Jiangxi was significantly higher than that of other varieties, while the palmitic acid content of a variety of *Camellia oleifera* oil, Yuekexia-2, was significantly higher (Su et al., 2014). Additionally, theThe fatty acid composition in Camellia oleiferacamellia oleifera seed oil samples also depends on the planting area. For example, Camellia oleifera from low latitudes (Northern Hemisphere) or warm regions in Heyuan, Guangdong showed lower oleic acid (18:1,78.9%) and higher linoleic acid content (18:2, 9.7%)(Zeng & Endo 2019). Therefore, the varieties of Camellia oleifera differ, and differences in their cultivationdistribution areas and climate can cause variations in the composition and yield of Camellia oleifera oil. Geographical location is an important factor that significantly affects the yield of Camellia oleifera oil (as shown in Table 1).

3. Methods of extracting active substances from camellia oil

3.1. Supercritical fluid extraction

Supercritical fluid extraction (SFE) is widely recognized as an effective and environmentally friendly technique for extracting oil from seeds. In particular, using supercritical carbon dioxide ($SC–CO_2$) in SFE offers a safe, fast, selective, and low-temperature approach for seed oil extraction. (Ahangari et al., 2021). This method employs supercritical fluids to separate oil from oil seeds at lower temperatures, resulting in enhanced oil yield and better preservation of heat-sensitive bioactive compounds in the oil (Liang et al., 2016). Compared to traditional methods of refining Camellia oleifera oil refining, which often typically involves complex deacidification and deodorization processes, this novelnew approach utilizes a combination of supercritical fluid extraction and molecular distillation (SFE-MD) was used to improve the quality of camellia oil. A series of important process parameters were investigated to obtain high-quality camellia oil. Compared with the camellia oil produced by supercritical fluid extraction (SFE), the acid value of camellia oil obtained by supercritical fluid extraction and molecular distillation was significantly decreased to 0.63 ± 0.01 from 2.93 ± 0.01 to 0.63 ± 0.01 mg KOH/g oil, without any change inof their fatty acid compositions. Furthermore, unsaponifiable matters inof camellia oil, such as γ-tocopherol, β-sitosterol, and squalene, could be effectively preserved withand there were no residual harmful substances. (Zhou et al., 2019).The effectiveness of the supercritical CO_2 extraction method in obtaining high-quality oil that meets national standards has been well established (Sahari and Amooi, 2013). Researchers have also explored supercritical extraction technology combined with microwave pretreatment to extract high-quality vegetable oil efficiently. More scientific and practical conditions have been identified through response surface optimization of the ultrasonic-microwave synergistic extraction process. This optimized process facilitates the extraction of high-quality *Camellia oleifera* oil and helps preserve the vitamin E in the oil (Huang et al., 2014).

Recent studies have compared the oil yield of different extraction methods for *Camellia oleifera* seeds, demonstrating that the SFE method achieved the highest oil yield (92.42%), followed closely by the solvent extraction (SE) method with a yield of (92.3%). On the other hand, water extraction (AE) and press extraction (PE) yielded lower oil percentages of 85.74% and 84.79%, respectively. The differences in oil yield between SFE 、SE、AE and PE statistically significant ($p < 0.05$), indicating the superior performance of SFE and SE methods (as shown in Table 2) (Liang et al. 2016).

3.2. Solvent extraction

The solvent extraction process, commonly using solvents such as hexane or n-hexane, is known for its simplicity and cost-effectiveness (Mwaurah et al., 2020). However, it is important to note that these solvents can havebe toxic and harmful effects. Solvent extraction is typically used for seeds with low oil content or for recoveringthe recovery of remaining oil from camellia seed cake. Unfortunately, the process of recovering oil with solvents can be complex and can lead to

Table 1
Oil content and fatty acid composition of *Camellia oleifera* in different regions.

Region	Hainan	Guangxi	Zhejiang	Guizhou	Jiangxi
Oil content	45.70–50.91	47.05–59.51	NM	35.07–53.47	11.60–29.60
Tetradecanoic C14:0 (%)	ND	0.09–0.32	ND	ND	ND
Palmitic acid C16:0(%)	8.46–11.39	13.05	7.75–11.30	6.77–9.04	9.00–11.50
Palmitoleic acid C16:1 (%)	ND	0.17–0.33	0.10	0.006–0.640	0.10
Stearic acid C18:0 (%)	2.32–3.09	1.85–3.71	1.80–3.65	1.36–2.56	1.20–1.60
Heptadecenoic C17:1 (%)	ND	0.07–0.11	ND	ND	ND
Oleicacid C18:1 (%)	75.99–83.43	70.13–79.75	78.55–83.90	77.97–83.77	76.30–80.30
Linoleic acid C18:2 (%)	4.45–8.86	5.76–8.98	4.10–12.40	5.50–10.90	8.90–12.20
Linolenic acid C18:3 (%)	ND	ND	0.10–0.65	0.27–0.51	0.30
Eicosonoic C20:0 (%)	ND	0.05–1.40	ND	ND	ND
Cis-11-Eicosenoic acid C20:1(%)	ND	ND	0.5–0.8	0.488–0.612	0.3–0.5
SFA(%)	11.46–14.43	13.61–17.95	9.90–13.40	8.88–11.03	10.50–12.90
MUFA(%)	ND	72.91–80.11	73.50–84.50	78.62–84.87	76.80–80.10
PUFA(%)	ND	5.85–9.14	4.20–13.05	5.80–11.21	9.20–12.50
USFA(%)	85.63–88.53	82.05–85.96	86.55–90.10	ND	ND
Reference	Yang et al.(2022)	Chen et al. (2011)	Cao et al. (2017)	(Long et al., 2022)	Zeng and Endo (2019)

ND: Not detected; NM: Not mentioned; SFA: Saturated fatty acid; MUFA：Monounsaturated fatty acid; PUFA：Polyunsaturated fatty acid; USFA：Unsaturated fatty acid.

Table 2
Oil yield of *Camellia oleifera* seeds by different extraction methods.

Extraction method	Oil yield (%)	Reference
Supercritical fluid extraction	92.42	Liang et al. (2016)
Solvent extraction	92.30	
Water extraction	85.74	
Press extraction	84.79	

environmental pollution. The storage and treatment costs associated with this method are high, and there is a significant loss of organic matter, which can adversely affecthave adverse effects on human health. (Liang et al. 2016). It is, therefore, necessary to consider these drawbacks when evaluating the solvent extraction process.

In their study, Xie et al. extracted components from *Camellia oleifera* shells using different solvents, including methanol, ethanol, and ethyl acetate, leading to the extraction of 12 compounds. Specifically, methanol was more effective in extracting c-sitosterol from the camellia shell (Xie et al., 2015). On the other hand, ethanol demonstrated a higher efficiency in extracting 5-hydroxymethylfurfural from the *Camellia oleifera* shell. Lastly, ethyl acetate efficiently extracted cis-isopropionic acid from the *Camellia oleifera* shell. These findings highlighted the solvent-dependent extraction of specific compounds in the *Camellia oleifera* shell.

A novel vortex-assisted liquid-liquid extraction was employed to analyze trace elements, revealing higher concentrations of iron (Fe) and manganese (Mn) in camellia oil than in other vegetable oils. Given that the iron content directly influences the storage stability of camellia oil, further investigation is required to determine its source. (Ni et al., 2016). This finding highlights the importance of understanding the factors that contribute to the iron content in camellia oil and its implications for storage and shelf life.

Commercially processed *Camellia oleifera* oil undergoes a series of steps, including seed cleaning, drying, pressing or solvent extraction, and solvent removal.

However, the traditional extraction methods process may retain harmful substances such as organic solvents, benzopyrene, aflatoxins, and heavy metals. This traditional process often yields.This results in low extraction efficiency and poor quality of Camellia oleifera oil quality, raisingleading to safety and environmental concerns. (Zhou et al., 2019). Furthermore, these retained substances may even pose harm to the human body(Liang et al. 2016).

Studies have also explored combining solvents for extracting oil from *Camellia oleifera* seeds. One such approach involves combining n-hexane and benzene and further treating them with methanol or ethanol to extract the non-lipid components. (Sahari and Amooi, 2013).

However, in recent years, there has been a growing interest in employing more environmentally friendly methods, including green solvents like water, ethanol, and CO_2, for the extraction process. These alternative solvents are considered more eco-friendly than traditional solvents like n-hexane and benzene.

3.3. Ultrasound-assisted extraction

Ultrasonic-assisted extraction offers several advantages. It reduces solvent consumption by facilitating efficient solvent penetration into the cells, thus requiring less overall volume. Additionally, it saves time by accelerating the extraction process through the disruptive action of ultrasound on cell structure. Ultrasonic-assisted extraction also yields more oil than traditional extraction techniques (Sahari and Amooi, 2013).

The extraction rate of *Camellia oleifera* saponin gradually increased with the prolongation of ultrasonic time. Considering factors such as energy consumption and extraction period, an ultrasonic duration of 30 min can achieve a stable and high extraction rate without incurring unnecessary energy costs or prolonging the overall extraction process (Du et al. 2015).

In one study, *Camellia oleifera* oil was extracted using a 90% methanol concentration, a 30 °C extraction temperature, a 1:7 solid-liquid ratio, and 30 min of extraction time. The study reported a 96.21% extraction rate of saponin, with a purity of 59.3% (as shown in Table 3) (Zong et al., 2019). Another study by Mohamed, Ibrahim, Abdel-Azim, and El-Missiry compared three different extraction methods: cold pressing, solvent extraction, and ultrasonic-assisted extraction (Mohamed et al., 2021). Analysis of the seed oil using gas chromatography-mass spectrometry revealed that the ultrasonic-assisted extraction method resulted in a higher oleic acid content than the other methods.

However, limited studies have been conducted in recent years on the ultrasonic extraction of *Camellia oleifera* oil and its practical components.

3.4. Microwave assisted extraction

Microwave-assisted extraction (MAE) is a novel extraction technique that combines microwave technology with traditional solvent extraction. This method has shown promising results in enhancing the quality of various extracts, including camellia oil. The application of microwave pretreatment within mcrowave-assisted extraction has been found to effectively increased the concentration of characteristic chemical

Table 3
Ultrasonic extraction process of saponins.

Extraction method	Extractive substance	Process condition	Extraction rate (%)	Reference
Ultrasonic extraction	Saponin	Methanol concentration 90 %; temparture30 °C; solid-liquid ratio 1:7; time:30 min.	96.21	(Du et al., 2015; Zong et al., 2019)

components and improved the oxidative stability of camellia oil (Ye et al., 2021). Malheiro et al. conducted a study confirming white and green tea water extracts, known for their high antioxidant content, could enhance oil stability when used in microwave cooking (Malheiro et al., 2012). The application of microwave-assisted extraction reduced the extraction time from 6 h to 4 min. This approach also resulted in a 50% reduction in the use of organic solvents while offering a 14% increase in extraction rate (He et al., 2014). Furthermore, increasing the microwave power and irradiation time led to a higher oil yield (Yingngam et al., 2021).

Microwave pretreatment increased the oil yield by 10%, phytosterol content by 15%, and tocopherol by 55% (as shown in Table 4) (Koubaa et al., 2016). The traditional extraction process consumes a large amount of solvent and has a long extraction time, which potentially causes the loss of active ingredients. Some scholars optimized the extraction process using the response surface method and improved the efficiency of polyphenol extraction from *Camellia oleifera* shell using a microwave-assisted extraction method. The optimal conditions were a liquid-solid ratio of 15.33: 1 (mL/g), microwave extraction time of 35 min, and 76°Cmicrowave extraction temperature (as shown in Table 4) (Zhang et al., 2011).

3.5. Enzymatic extraction

The aqueous enzymatic extraction method is a new green extraction technology that uses enzymes to extract oil (Mwaurah et al., 2020). It is considered to replace traditional solvent extraction methods due to its high yield and high quality of bioactive compounds(Jiamphun and Chaiyana, 2022). Unlike other extraction methods, the aqueous enzymatic method mainly uses water as a solvent to separate oil by using enzyme activity to catalyze reactions with substrates (Mwaurah et al., 2020).

Compared with solvent extraction, water extraction has several advantages, including enhanced safety, environmental friendliness, and cost-effectiveness. Water extraction typically has lower energy consumption, operational costs, and capital investments. However, one drawback of this method is the extended processing time, which leads to higher drying costs for enzyme treatment and potentially lower oil production rates (Yusoff et al., 2015).

The selection of enzymes in the extraction process is crucial and depends on the composition and structure of camellia oil components. Furthermore, addingthe addition of alcium chloride during the extraction process helps address the issues associated with n-hexane extraction, enhancing efficiency and environmental friendlinessmaking it more efficient and environmentally friendly (Meng et al., 2018b).

Table 4
Microwave extraction of different active ingredients.

Extraction method	Extractive substance	Process condition	Extraction rate (%)	Reference
Microwave-assisted extraction	Sterol	–	Increase by15%	Koubaa et al. (2016)
Microwave-assisted extraction	Tocopherol	–	Increase by55%	Koubaa et al. (2016)
Microwave-assisted extraction	Polyphenol	Liquid-solid ratio 15.33:1 ml/g,time 35min, temperature 76 °C	–	Zhang et al. (2011)

A study comparing the effects of five different enzymes on oil yield found that protease and cellulase yielded the highest oil, reaching 63.87% and 61.25%, respectively. Combining enzymes further increased the oil yield to 77.09% (Wu et al., 2015).

A study investigating the use of composite enzymes to enhance *Camellia oleifera* oil yield by 92.45% determined the optimal extraction process through single-factor and response surface tests. This process involved adding 0.13% composite enzyme, using a material-water ratio of 1:3.9, and allowing the enzyme to act for 4 h(as shown in Table 5) (Zhou et al., 2016).

Moreover, the degree of crushing *Camellia oleifera* seed kernels significantly impacted oil extraction using aqueous enzymatic extraction. Moderate crushing reduced the average particle size of the *Camellia oleifera* seed kernels, leading to an improved oil extraction rate of 96.66%. However, excessive particle size reduction caused increased dispersion of oil and proteins during the oil extraction process. This process enhanced the extraction workload and made oil extraction from the emulsion complex. (Xie et al. 2016).

Despite its advantages, aqueous enzymatic extraction has certain drawbacks. It fails to produce the characteristic aroma of oil and leaves behind residual oil or chemicals like hexane, necessitating additional steps or substances for removal, increasing overall cost and complexity. (Zhang et al., 2019).

However, there are advantages to aqueous enzymatic extraction. Aqueous extraction allows for the simultaneous recovery of proteins, polysaccharides, and oil from sources such as *Camellia oleifera* seeds. Enzyme treatment facilitates the hydrolysis of the seed cell walls, releasing several antioxidant compounds. As a result, the enzymatically extracted oil contains higher levels of bioactive components. Comparative studies have shown significantly higher vitamin E and squalene in enzyme-extracted oil than in hexane-extracted oil (Fang et al., 2016).

A study compared the effects of different extraction methods on the quality of camellia oil. The aqueous enzymatic method yielded camellia oil with the lowest acid value, indicating better oil quality. However, this method resulted in oil with the lowest antioxidant activity (Li et al., 2015).

Furthermore, the enzyme extraction method yielded camellia oil with lower phenolic compounds than other methods. Additionally, the phospholipid content of the *Camellia oleifera* oil obtained through the aqueous enzymatic method was below 5 μg/g, an ideal low value for phosphorus content in oil (Fang et al., 2015).

Despite these advantages, the enzyme extraction method has certain limitations. Enzymes are often expensive, making their use economically challenging. Separating the enzyme from the *Camellia oleifera* oil after extraction poses difficulties. Recovering enzymes for reuse is also problematic. These factors have contributed to the limited adoption of the enzyme extraction method in the *Camellia oleifera* oil industry (Peng et al., 2019).

Table 5
Process conditions of compound enzyme extraction of *Camellia oleifera* oil.

Extraction method	Extractive substance	Process condition	Extraction rate (%)	Reference
Enzymes extraction	*Camellia oleifera* oil	Addition amount: 0.13 %, ratio of material to water 1: 3.9, time:4 h	92.45	Zhou et al. (2016)

3.6. Subcritical fluid extraction

Subcritical water extraction is widely used for extracting flavor and fragrance compounds, essential oils, fatty acids, carotenoids, and phenolic compounds. It is gaining recognition for its advantages over traditional extraction methods. This method offers several benefits, including faster extraction rates, reduced solvent usage, prevention of thermal degradation of heat-sensitive compounds, elimination of organic solvents, and minimizing environmental impact (Chemat et al., 2019).

Ultrasonic-assisted subcritical fluid extraction, a novel process, has been developed to provide an efficient and solvent-free approach to extracting essential oils(Zhao et al., 2019). Wu et al. investigated microwave pretreatment and analyzed experimental results using the subcritical water treatment method. Subcritical water pretreatment can improve the value addition to *Camellia oleifera* seed kernel deep processing products and the comprehensive utilization rate of *Camellia oleifera* seed.

Subcritical water extraction has been recognized as an effective and environmentally friendly method for the simultaneous extraction and separation of *Camellia oleifera* oil and saponin (Wu et al., 2018). Recent studies have explored a new subcritical fluid extraction method with lower temperature and higher pressure than supercritical extraction. Through three experimental validations, continuous extraction using n-butane achieved an impressive average extraction rate of 99.12 ± 0.20% for camellia oil (Wu et al., 2018). Furthermore, high-performance liquid chromatography (HPLC) analysis revealed that Camellia oleifera oil produced by continuous subcritical n-butane fluid extraction did not contain benzo[a]pyrene, an environmental hazard. This extraction technique yielded a high-quality product and demonstrated its environmental friendliness(Miao et al., 2013).

3.7. Other extractions

The extraction methods discussed above each possess their own distinct set of advantages and disadvantages. Scholars have developed a few additional environmentally friendly techniques with high extraction efficiency. However, these methods have yet to see widespread adoption.

Scholars have recently focused on studying the potential of endophytic fungi capable of producing large quantities of polyphenols through biological fermentation. This approach screens endophytic fungi from tea plants that produce polyphenol oxidase and optimizes enzyme production conditions (as shown in Table 6)(Zhang, Wu, & Yang, 2015). Furthermore, a new environmentally friendly extraction technique called solvent-free extraction has been introduced, offering advantages in terms of time efficiency and convenience by eliminating the need for subsequent wastewater treatment. For example, solvent-free microwave extraction utilizes fresh plant materials without requiring the addition of any solvents (Chemat et al., 2019).

Another notable endeavor involved developingthe development of a novel process for efficiently extracting high-quality camellia oil. This method usedutilized an aqueous phase treatment.Through this approach achieved, a remarkable extraction rate of 94.79% for camellia oil without generating was achieved, and importantly, this method does not generate wastewater during the extraction process(as shown in Table 6) (Lv and Wu, 2019).

AB-8 macroporous adsorption resin and Sephadex G-15 were utilized to obtain saponin with a purity of 82.5% (as shown in Table 6)(Zhao et al., 2020). Innovative technologies, such as the combination of microwave and centrifugal force, have been used to extract volatile and non-volatile compounds in a more environmentally friendly manner (Angoy et al., 2020).

Certain studies have explored silver ion complexation to separate squalene from *Camellia oleifera* oil. The optimal process conditions included a methanol concentration of 70% (v/v), an $AgNO_3$ concentration of 0.6 mol/L, a reaction time of 12 h, and a temperature of 0 °C (as shown in Table 6)(Xiao et al., 2016).

Moreover, aA novel extraction method called pressurized hot water extraction has beenwas employed to extract and identify five flavonoid glycosides from defatted Camellia oleiferaoil seeds (by-products) of Camellia oleifera. Compareding the results with to ultrasonic-assisted extraction (UE), pressurized hot water extraction demonstrated a higher recovery rate (78.5% vs. 68.4%) and total yields of flavonoid glycosides (18.8% vs. 15.91 mg/g), demonstrating its. Moreover, this method exhibits high extraction efficiency without causing harm to the environmental harm. (as shown in Table 6)(Liau et al., 2017).

4. Fatty acid composition

Camellia oleifera oil is a highly nutritious edible oil containing abundant unsaturated fatty acids comprising more than 85% of its composition. In particular, the content of oleic acid ranges from 74% to 89%, significantly higher than that of rapeseed, peanut, and soybean oils (Zhang et al., 2022). The human body readily absorbs oleic acid, which is vital to metabolism. It can effectively reduce cholesterol levels in the intestine, regulate blood lipids, delay atherosclerosis, and prevent cardiovascular diseases such as hypertension and hyperlipidemia(Meng et al., 2018a). *Camellia oleifera* oil mainly contains three fatty acids: oleic acid, stearic acid, and palmitic acid. Its fatty acid and triglyceride composition differ significantly from other oils. The content and type of fatty acids determine the characteristics and nutritional value of vegetable oils(Yang et al., 2016). The content and type of fatty acids determine the characteristics and nutritional value of vegetable oils. Studies have shown that oleic acid not only inhibits melanin production by inhibiting tyrosinase and tyrosinase-related protein-2 activity but also demonstrates antioxidant activities(Chaikul et al., 2017).

Previous research on vegetable oils mainly focused on their fatty acid composition. (Shen et al., 2023). Researchers have compared the fatty acid composition of camellia oil with olive oil, concluding that camellia oil can be comparable with olive oil in terms of chemical composition and nutritional value(Yang et al., 2016). As a result, Camellia oleifera oil is frequently referred toalso known as "oriental olive oil." The oil content and fatty acid composition are essential factors for evaluating the quality and yield of edible oils. Gas chromatography and high-performance liquid chromatography are commonly employedused methods for determiningto determine the fatty acid composition of edible oils(Yuan et al., 2013). Unsaturated fatty acids, such as linolenic acid and linoleic acid, are essential for human health since they cannot be synthesized in the human body and must be exogenously from diet or dietary supplements (Chew, 2020). Zhang et al. analyzed the oil content and fatty acid composition of *Camellia oleifera* seeds originating from Yunnan and

Table 6
Other extraction methods.

Extraction method	Extractive substance	Process condition	Extraction rate	Reference
Bio-fermentation	Polyphenol	–	–	Zhang et al. (2016)
New water phase process	*Camellia oleifera* oil	H_2O:1.2g; NaCl：0.1g; $NaHCO_3$:0.008 g	94.79%	Lv and Wu (2019)
Adsorption composite method	Saponin	Compound:AB-8 macroporous resin; dextran gel-15	Purity: 82.5%	Zhao et al.(2020)
Silver ion complexation	Squalene	Methanol:70%,$AgNO_3$:0.6 mol/L; time:12h; temperature:0 °C	–	Xiao et al.(2016)
Pressurized hot water extraction	Flavonoid	Pressurized hot water	15.91 mg/g	Liau et al. (2017)

Henan Provinces(Zhang et al., 2015). Their findings revealed that *Camellia oleifera* oil from these regions contained several fatty acids, such as palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, and arachidonic acid (cis-11-eicosenoic acid) (as shown in Table 7).

5. Bioactive components

5.1. Vitamin E

Vitamin E is a fat-soluble vitamin found in many plants and abundant in plant seeds(Nowicka and Kruk, 2017). It is highly concentrated in the seed coat and embryo of plant seeds(Shen et al., 2023). The main component of vitamin E found in most vegetable oils is tocopherol. Lv, Sun, and Geng conducted a study to determine the vitamin E content in *Camellia oleifera* oil seeds using colorimetry and gas chromatography, reporting a concentration of 23.93 mg/100 g.

Experiments(Shi, T., Wu, Jin and Wang, 2020) have demonstrated that among all tocopherols, the α-tocopherol content of *Camellia oleifera* oil exhibits the highest biological efficacy (Fig. 2). *Camellia oleifera* also constituted several other bioactive functional components, including polar phenols (mainly phenolic acids, 20.56–39.47 mg/kg) and tocopherols (153–771 mg/kg α-tocopherols, 9.4–59 mg/kg γ-tocopherols, and 0.27–28 mg/kg δ-tocopherols(as shown in Table 8).

In recent years, research on tocopherol has shifted from investigating its antioxidant effect to its anti-inflammatory and non-antioxidant properties(Ahsan et al., 2015). A substantial number of experimental studies have consistently demonstrated the diverse biological effects of tocopherol, which include its antioxidant properties, anti-inflammatory potential, anti-tumor activity, and ability to prevent cardiovascular diseases. Due to their robust antioxidant capacity, tocopherol monomers are important in various industries in China's oil science (Che et al., 2017).

5.2. Saponins

In addition to tea, *Camellia oleifera* seeds are considered a valuable natural source of saponin (Guo et al., 2018). *Camellia oleifera* cake, a by-product of Camellia oleifera oil production, is often used to clean fish ponds or incorporated intobecome fertilizers ((Yu et al., 2022); Yu et al., 2022). Most Camellia oleifera seed cakes are beingcurrently discarded, wastingresulting in a waste of valuable resources and causing environmental damage. However, it is important to note that Camellia oleifera seeds cake consists of various, a byproduct of Camellia oleifera seeds, contains an abundance of saponin, also known as saponin. *Camellia oleifera* seeds cake consists of various types of saponins, specifically oleanane triterpenoid saponins. These compounds are known for their emulsifying properties, especially the saponin, an excellent foaming stabilizer. Despite its beneficial properties, extracting saponin from *Camellia oleifera* cake remains challenging (Zhang et al., 2019). In the

Table 7
Fatty acid composition of *Camellia oleifera* oil.

Fatty acid	Content (%)	Reference
Linoleic acid(C18:2)	8.96	
Linolenic acid(C18:3)	0.28	Yang, C., Liu, X., Chen, Z., Lin, Y., & Wang (2016)
Stearic acid (C18:0)	1.87	
Palmitic acid(C16:0)	8.12	
Palmitoleic acid (C16:1)	0.12	
Oleic acid(C18:1)	77.81	Zhang et al. (2022)
Arachidonic acid (C20:0)	0.32	
SFA	10.93	
MUFA	78.09	
PUFA	10.79	

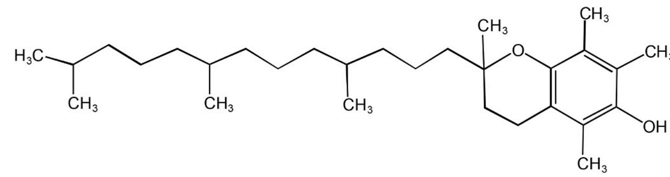

Fig. 2. Chemical structure diagram of α-tocopherol.

Table 8
Contents of Vitamin E in *Camellia oleifera oil.*

Bioactive Components	Content (mg/kg)	Reference
α- tocopherol	153–771	Shi, T., Wu, Jin and Wang (2020)
γ-tocopherol	9.4–59	
δ-tocopherol	0.27–28	

study by Lv, Sun, and Geng, the saponin content in *Camellia oleifera* seeds was determined using colorimetry and gas chromatography, reporting a calculated concentration of 3.70 mg/100 g (as shown in Table 9).

Triterpenes possess beneficial properties such as anti-high cholesterol and anti-hyperlipidemia activities(Luan et al., 2020). Similarly, triterpenoid saponins have demonstrated antibacterial and antifungal capabilities. At a concentration of 0.1 mg/mL, purified total saponins significantly inhibited mycelial growth, suggesting their potential for developing safe and environmentally friendly fungicides (Zhang et al., 2014). Additionally, these saponins have been utilized as natural surfactants, preservatives, and antifungal agents (Cheok et al., 2014). Moreover, saponin has been found to inhibit cell proliferation and exhibit heavy metal chelation properties. Besides its immune-modulating effects, saponin plays a role in regulating lipid metabolism in humans and animals, highlighting its various biological activities. (Jiang et al., 2022).

In current research on *Camellia oleifera* oil, there is a scarcity of reports regarding the qualitative and quantitative analysis of triterpenoids in *Camellia oleifera* seed cake. Nonetheless, some studies have highlighted the neuroprotective effects of saponin extracted from *Camellia oleifera* on nerves. Additionally, both saponins and their hydrolysates have demonstrated significant anti-inflammatory and analgesic properties. (Ye et al., 2014).Furthermore, research suggests that saponins can play a role in regulating the gastrointestinal system(Song et al., 2018). A study by Fu et al. revealed the potential of saponins in combating cancer cells (Fu et al., 2018). However, limited research exists on the anti-tumor mechanism of saponin derivatives. Triterpenoid saponins have also shown promise as a potential treatment for diabetes(Luan et al., 2020).

5.3. Polyphenol

Polyphenols are compounds with numerous phenolic hydroxyl structures(as shown in Fig. 3).The *Camellia oleifera* shell is a valuable source of polyphenols, making its green extraction method highly significant in ensuring efficient processing and a high yield(Javed et al., 2022).

Wang et al. developed a biorefinery process for extracting bioactive compounds and bio-oil from *Camellia oleifera* shells(Wang et al., 2019). However, most research studies have primarily focused on extracting phenolic compounds from *Camellia oleifera* seeds or seed meals,

Table 9
Contents of saponins in *Camellia oleifera*.

Bioactive Components	Content(mg/100g)	Reference
Saponins	3.70	Lv et al. (2014)

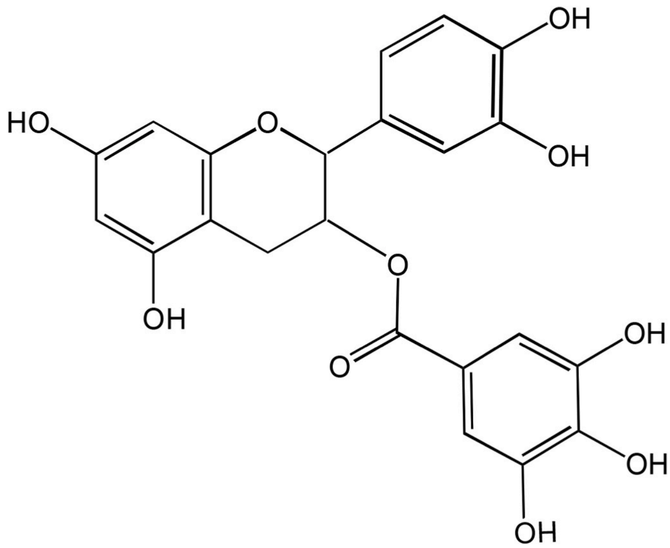

Fig. 3. Chemical structure diagram of polyphenol.

disregarding the potential utilization of phenolic compounds in the shell. The disposal of *Camellia oleifera* shells as waste during oil extraction has adverse environmental consequences, contributing to pollution. This practice results in the wastage of valuable polyphenols in the *Camellia oleifera* shell. Thus, exploring effective methods to utilize the resources available in *Camellia oleifera* shells is crucial. Using colorimetry and gas chromatography, Lv, Sun, and Geng determined that the tea polyphenol content in *Camellia oleifera* oil is 1.26 mg/100 g (as shown in Table 10).

The nutritional value and health benefits of tea are closely linked to its high polyphenol content, primarily catechins. Similarly, the antioxidant properties of camellia oil arise from its abundance of phenolic compounds. Total phenolics can serve as good quality indicators in tea cultivation (Wang et al., 2014). Polyphenols act as natural antioxidants, with catechin compounds being the main constituents, comprising approximately 65–80% (as shown in Table 10). Catechin monomers have demonstrated anti-inflammatory, antioxidant, and immunomodulatory effects. Studies have indicated that polyphenols may reduce the risk of periodontal and inflammatory bowel disease (Xiao et al., 2017).

Camellia oleifera oil comprises various phenolic compounds with a broadthat possess a wide spectrum of biological activities. They function as scavengers of free radicals within the human body, inhibit lipoxygenase and lipid peroxidation in skin mitochondria, and possess anti-aging properties. (Mumtaz et al., 2021). In a swimming experiment conducted on mice, the combination of polyphenol-rich *Camellia oleifera* oil and bis(2-cbrboxyethylgermanium(IV) sesquioxide) (Ge-132) significantly increased the exercise endurance of the mice. Furthermore, the *Camellia oleifera* oil complex enhanced liver glycogen content and exhibited anti-fatigue effects (Hu et al., 2015). Chang et al. (2020) investigated the phytochemical components of *Camellia oleifera* oil and confirmed that polyphenol extracts possessed anti-inflammatory effects. However, due to the diverse nature of polyphenols, further research is necessary to isolate and identify the specific active anti-inflammatory compounds present in *Camellia oleifera* oil.

Apart from their antioxidant properties, polyphenols also exhibit various physiological functions, including alleviating allergies, detoxifying the body, and nourishing the skin. These beneficial effects make *Camellia oleifera* oil extract promising as a traditional Chinese medicine beverage (Rahayu and Timotius, 2022).

However, some studies have indicated that active substances such as polyphenols and antioxidants tend to disappear during the refining process. Furthermore, the stability of the oil decreases after deacidification, decolorization, and deodorization (Qi et al., 2015). These drawbacks pose a significant challenge in understanding the active components of camellia oil.

The phenolic compounds present in *Camellia oleifera* oil exhibit significant antioxidant properties. Moreover, research has demonstrated that the human body can effectively enhance its antioxidant system by consuming natural antioxidants. Thus, finding natural antioxidant active substances through a simple pretreatment process has become a focal point of research (Feng et al., 2023).

Table 10
Contents of polyphenol in *Camellia oleifera*.

Bioactive Components	Content（mg/100g）	Reference
Polyphenol	1.26	Lv et al. (2014)
Catechins	0.82–1.01	Xiao et al. (2017)

5.4. Sterol

As one of the primary constituents in vegetable oil, sterols typically makes up around 97.0–98.0% of the total oil components in *Camellia oleifera* oil(Wang et al., 2017). Sterols are the most important unsaponifiable compounds in edible oils. The most common sterols in vegetable oils are β-sitosterol, camphor sterol, and stigmasterol(as shown in Table 11) (Yang et al., 2016). These natural compounds are crucial in reducing cholesterol levels within the body. Moreover, sterols exhibit remarkable antioxidant properties and play crucial roles in essential physiological functions such as growth promotion, immune regulation, and hormone regulation. Phytosterols (plant sterols) have been labeled as the "key to life" by scientists due to their potential as drugs for cancer prevention and treatment (Xie et al., 2015).

Currently, limited research is available on qualitatively analyzing sterols in *Camellia oleifera* oil. Phytosterols obtained through diet serve as the sole source for individuals, and their intake has been linked to a protective effect against tumor growth and metastasis by inhibiting cholesterol absorption (Blanco-Vaca et al., 2019). The interaction between phytosterol derivatives and bile salts plays a crucial role in these molecular mechanisms, which may lead to the development of cholesterol absorption inhibitors (Hu et al., 2023). These inhibitors can reduce harmful cholesterol levels in the bloodstream and lower the risk of developing atherosclerosis (Santanatoglia et al., 2023). Consequently, long-term human studies have explored phytosterols as a dietary alternative for managing cholesterol levels effectively(Cedó et al., 2019).

A few qualitative and quantitative studies on sterols in *Camellia oleifera* oil have been conducted in recent years. Therefore, the effective extraction of sterols in *Camellia oleifera* oil and the application of its physiological activity need to be further studied.

5.5. Squalene

Squalene is a triterpenoid aliphatic hydrocarbon naturally found in various animals and plants. It derives its name from its abundant presence in shark liver oil (Fig. 4) (Cayuela and García, 2018). It consists of a chain structure of triterpenoids comprising six isoprene units (Sánchez-Fidalgo, Villegas, Rosillo, Aparicio-Soto and de la Lastra,

Table 11
Contents of Sterol in *Camellia oleifera* oil.

Bioactive Components	Content (mg/100 mg)	Reference
Ergosterol	5.1–20.6	Yang, Liu, Chen, Lin, & Wang (2016)
Lupeol	7.3–18.6	
β-Amyrin	42.2–59.5	
Lanosterol	50.4–270.8	
Tirucallol	7.3–30.6	
7-Stigmastenol	24.5–178.2	
Cycolartenol	13.5–23.6	

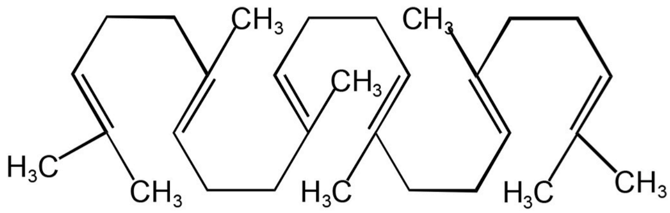

Fig. 4. Chemical structure diagram of Squalen

2015). A study detected seven sterols and squalene in three different *Camellia oleifera* oils (Yang et al., 2016). The content of squalene extracted from *Camellia oleifera* oil varied between 0.29% and 2.98%, depending on the extraction method used(as shown in Table 12)(X. Liu et al., 2014; Z. X. Liu et al., 2014).

As mentioned in previous studies, squalene hasexhibits efficient antioxidant properties. In a study conducted on mice, squalene playedit was found that squalene plays a significant protective role againstin acute alcoholic liver injury. The protective effect mechanism may behind this protective effect might involve the inhibition of ethanol-induced lipid peroxidation in liver cell membranes induced by ethanol, thereby preventing the formation of malondialdehyde and subsequent liver function damage (Miao et al., 2015). Squalene is commonly used as a vaccine adjuvant, formulated into an emulsion, and enhances the immune response in approved vaccines (Fisher et al., 2023). Studies have shown various biological effects of squalene on the immune system, including systemic impacts on T lymphocyte and dendritic cells, improved immune barrier function, anti-inflammatory effects, and potential autoimmune side effects. In a study, squalene was added to *Camellia oleifera* oil as a complex and administered to rats with hyperlipidemia-induced reproductive injury for 30 days. The results showed that squalene supplementation reduced blood lipids, increased testosterone levels, and enhanced sperm count in the cauda epididymis. It also improved penis and testicular damage and promoted erectile function and sexual function recovery. The combined effect of squalene and *Camellia oleifera* oil was better than that of the *Camellia oleifera* oil alone (Lou-Bonafonte et al., 2018). While current research on squalene has proposed potential molecular mechanisms, the exact mode of action remains to be fully elucidated.

5.6. Flavonoids

Flavonoids have an aromatic structure(Fig. 5), which is crucial in protecting biological systems (Liau et al., 2017). These secondary metabolites are commonly found in plants and seeds, offering several health benefits. Previous study conducted a comprehensive review of research on the impact of dietary flavonoids on gut microbes and their metabolites (Chu et al., 2023). Their findings suggest that flavonoids have the potential to enhance cognitive function by modulating the gut-brain axis. Dietary factors play pivotal roles in governing essential biological processes and exert significant influence on the regulation of pathological progression at every stage of life. Han et al. (2023) have reviewed how dietary flavonoids serve as natural epigenetic modulators, contributing to the discovery of biomarkers for diabetes prevention and the development of alternative therapies. *Camellia oleifera* oil contains significant amounts of kaempferol glycosides, particularly camellia glycosides (Liu et al., 2014). The total flavonoid content in 40 different varieties of *Camellia oleifera* oil was determined by an ultraviolet

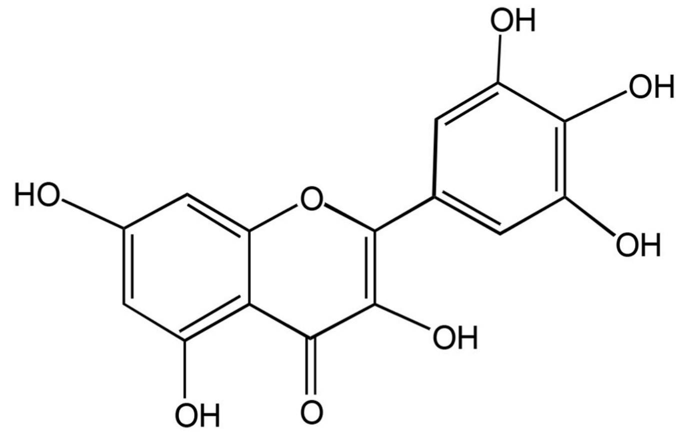

Fig. 5. Chemical structure diagram of flavonoid.

spectrophotometer, with the concentration ranging from 2.84% to 8.68% (as shown in Table 13) (Yu et al., 2022).These compounds possess antioxidant and anti-inflammatory properties, leading to protective effects against various diseases like cancer, cardiovascular issues, and inflammation (Chen et al., 2009). Natural flavonoids also exhibit gastric protection, anti-Helicobacter pylori activity, and antidiabetic and antioxidant effects (Semwal et al., 2021).

Studies have shown that total flavonoids in camellia seed oil can beare extracted usingby 80 % ethanol, leading to the rapid identification ofand four compounds are quickly identified. Kaempferol glycosides are the main flavonoids in camellia seed, but further research is needed to purify each compound and study their effects on inflammatory signaling pathways *in vitro and in vivo*(Liu et al., 2014).

6. Biological function of *Camellia oleifera* oil

6.1. Antioxidant activity

Camellia oleifera oil is rich in antioxidants, which can provide several benefits for gastrointestinal health (Fig. 6). Studies have demonstrated that *Camellia oleifera* oil can effectively protect the gastrointestinal mucosa by reducing lipid peroxidation, apoptosis-related proteins, pro-inflammatory cytokines, and nitric oxide (NO) production. Additionally, it increases the activity of antioxidant enzymes. These findings indicated that Camellia oil has the potential to treat gastric injury. (Tu et al., 2017).

Camellia oleifera oil contains significant amounts of carotenoids, polyphenols, and vitamin E, all of which act as natural antioxidants (Sahari and Amooi, 2013). Its main components constituents include unsaturated fatty acids, polyphenols, and squalene. These compounds possess the ability to eliminate oxygen free radicals, inhibit lipid peroxides, and enhance the activity of antioxidant enzymes like such as superoxide dismutase and catalase. Consequently, they play a crucial roleperform a vital function in maintaining the balance between oxidation and antioxidation, thereby protecting the body against diseases caused byfrom oxidative damage (Li et al., 2020). *Camellia oleifera* oil has a strong peroxidation inhibition capacity compared to other edible oils (Fig. 6). The extraction of saponins, proteins, and polysaccharides from defatted *Camellia oleifera* seeds has also been studied. These experiments revealed that the antioxidant activity of proteins and polysaccharides in *Camellia oleifera* oil surpasses that of saponins (Li

Table 12
Contents of Squalene in *Camellia oleifera* oil.

Bioactive Components	Content (mg/ 100g)	Reference
Squalene	22.3–63.2	Yang, Liu, Chen, Lin, & Wang(2016)

Table 13
Contents of Flavonoids in *Camellia oleifera* oil.

Bioactive Components	Content (%)	Reference
Flavonoid	2.84–8.68	Yang, Liu, Chen, Lin, & Wang (2016)

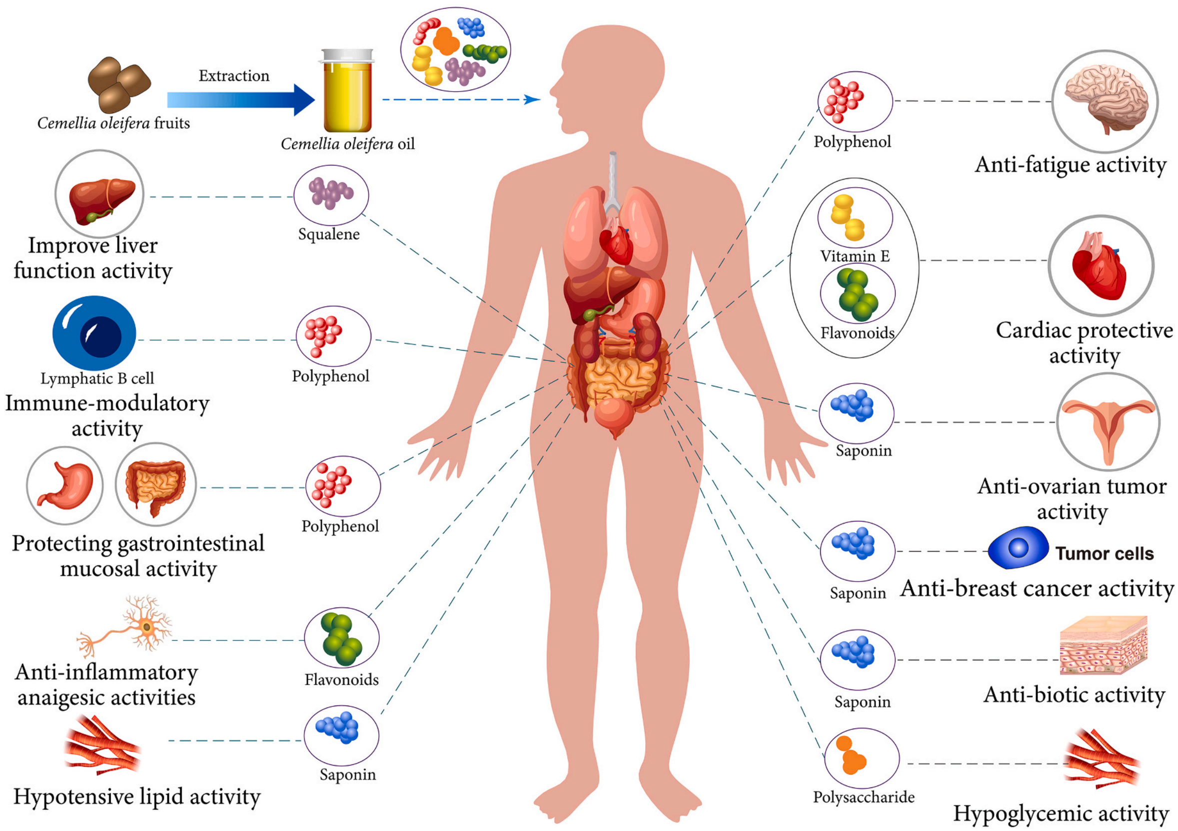

Fig. 6. Activity diagram of *Camellia oleifera* oil.

et al. 2014).

6.2. Anticancer activity

In recent years, numerous studies have demonstrated the inhibitory effects of triterpenoid saponins in *Camellia oleifera* on various cancer cells (Zong et al., 2015; Zong et al., 2016). As a result, Camellia oleifera has been proven to possess anti-cancer activity(Fig. 6) (Zong et al., 2016; Zhou et al., 2014; Zhang et al., 2014). Wu et al. extracted and identified over 30 saponins from *Camellia oleifera* seed cake. It was determined that compounds 1 and 4, namely C1 and C4, were novel saponin derivatives with anti-tumor properties. Tea saponins could be potentially viable candidates for the treatment of human ovarian cancer and breast cancer (Jia et al., 2017; Chen et al., 2013; Wu et al., 2022).

An anticancer potential of a new glycoprotein, COG2a, derived from *Camellia oleifera* seeds, has been identified, having an average molecular weight of 25.9 kDa. This glycoprotein is a promising natural compound for anticancer therapy due to its potential to elicit fewer side effects (Li et al., 2019). Furthermore, triterpenoid saponins have been isolated from *Camellia oleifera*. Two particular saponins, saponin B1 and camellia saponin B2, exhibited significant inhibitory effects on the proliferation of human lung cancer cells at a concentration of 10 μM. Saponin B1 achieved an inhibition rate of 94.44%, while camellia saponin B2 demonstrated an inhibition rate of 79.12%. Both saponins possess cytotoxic activity(Di et al., 2017).

The triterpenoid saponins in *Camellia oleifera* have been identified as a potential candidate for cancer treatment (Luan et al., 2020). However, further research is needed to understand their specific anticancer activity better.

6.3. Anti-inflammatory and antibacterial activities

Studies have shown that the bioactive components of *Camellia oleifera* oil and camellia seed cake extracts can enhance the activity of antioxidant enzymes, inhibit the activation of nuclear translocation of nuclear factor-kappa B (NF-κB), thereby inhibiting the production of inflammatory cytokines, and have anti-inflammatory activity (Fig. 6) (Xiao et al., 2017).

Pretreatment with *Camellia oleifera* oil slightly enhanced antioxidant and antioxidant enzyme activities in rats, and significantly reduced inflammatory damage and lipid peroxidation, thereby improving acetic acid-induced colitis. The results showed that edible *Camellia oleifera* oil had strong antioxidant and anti-inflammatory effects. Compared with soybean oil and olive oil, the intake of camellia oil enhanced the ratio of Firmicutes/Bacteroidetes, relative abundance of the Bifidobacterium, the α-diversity (Lee et al., 2018). Moreover, *Camellia oleifera* seeds can regulate the gut microbiota, leading to enhance richness and diversity of the gut microbiota and ultimately improving colitis. (Fig. 6).

Camellia oleifera seeds have an excellent antimicrobial effect (Feng et al., 2016). The saponins in *Camellia oleifera* seeds had antibacterial activity and a good antibacterial effect on *Escherichia coli* and *Staphylococcus aureus* (Fig. 6).The minimum inhibitory concentrations were 1 mg/mL and 0.5 mg/mL, respectively. The minimum bactericidal concentration was 4 mg/mL (Zhao et al., 2020). The *Camellia oleifera* oil saponin hydrolysate (Ye et al., 2014) and the biflavonoids in the camellia seed shell (Zhang and Li, 2018) also have anti-inflammatory and analgesic activities.

There are few human studies on the anti-inflammatory effects of *Camellia oleifera* oil showing that *Camellia oleifera* oil can improve liver function and antioxidant capacity, making it a potential adjuvant for liver fibrosis treatment (Fig. 6) (Lei et al., 2020). The formation and accumulation of advanced glycation end products (AGEs) are related to the progression of many aging-related diseases. Because the AGE receptor is highly related to inflammation, *Camellia oleifera* seed cake extract has a strong inhibitory effect on the formation of AGEs, demonstrating its anti-inflammatory activity (Sato et al., 2017).

A study demonstrated that *Camellia oleifera* oil exhibits promising effects in reducing dermatitis and alleviating scratching in mice with specific dermatitis induced by 2,4-dinitrochlorobenzene. The oil facilitated the development of a healthy skin barrier and suppressed the production of inflammatory cytokines in the mice's serum and skin tissues. These findings indicate that *Camellia oleifera* oil possesses antipruritic and anti-inflammatory properties, indicating its potential as a valuable natural alternative for dermatitis treatment (Fig. 6) Zhang et al., 2022(). Additionally, *Camellia oleifera* seed cake extract demonstrated a reduction in the expression level of pro-inflammatory cytokines, increased collagen synthesis, protected the skin from burn-induced inflammation in mouse burn experiments, and promoted wound healing in a dose-dependent manner. The extract also reduced the expression levels of various cytokines, including interleukin- 6, tumor necrosis factor α, interleukin-1β, monocyte chemotactic protein-1, transforming growth factor-β, interleukin-10 and inflammation-related factor inducible nitric oxide sythase, and played played an excellent effect (Liu et al., 2020).

6.4. Antihypertensive and hypoglycemic activity

Camellia oleifera oil offers diverse health benefits. Studies have indicated its ability to enhance the immune system and regulate blood cholesterol levels, thereby having an anti-dyslipidemic effect (Fig. 6) (Luan et al., 2020). In addition, there is growing interest in incorporating edible oils into dietary interventions for reducing blood pressure. Studies have indicated that camellia oil can help lower blood pressure by regulating the balance between vasoconstrictors and factors that promote vasodilation in the bloodstream (Guo et al., 2020).

Furthermore, a cell line called saponin A2 derived from *Camellia oleifera* oil displayed anti-hyperlipidemic activity and could potentially treat hyperlipidemia. However, further research is needed to understand its mechanism of action in the human body (Luan et al., 2020).

Another beneficial component of camellia oil is the polysaccharides derived from *Camellia oleifera* seed cake, which contain binding proteins and exhibit hypoglycemic activity (Fig. 6) (Gao et al., 2022). This suggests that *Camellia oleifera* seed cake polysaccharide could serve as a potential hypoglycemic agent.

Overall, these findings highlight the potential health benefits of *Camellia oleifera* oil and its components, but more research is needed to understand their mechanisms of action and effects on human health better.

6.5. Cardiac protective activity

Several studies have demonstrated that consuming *Camellia oleifera* oil can reduce the risk factors associated with cardiovascular disease (Fig. 6) (Huang et al., 2023).

Some studies (Ibrahim et al., 2020) involved recording and analyzing the dietary intake of *Camellia oleifera* oil in individuals with hypercholesterolemia. *Camellia oleifera* oil was more effective in preventing cardiovascular disease than soybean oil and other blended oils. The observed effects may be attributed to squalene, which is abundant in *Camellia oleifera* oil and possesses antioxidant properties that contribute to its cardioprotective effects. Squalene, an intermediate precursor of cholesterol, also aids in lowering cholesterol levels.

6.6. Immunoregulatory activity

In certain studies, polysaccharides have been extracted from *Camellia oleifera* shells, and polysaccharides have been obtained through hot water extraction, 80% ethanol precipitation, and 25% activated carbon adsorption. The findings from these studies indicated that *Camellia oleifera* oil polysaccharides have immunomodulatory properties in RA W264.7 macrophages by activating the mitogen-activated protein kinase and nuclear translocation of NF-κB signaling pathways (Xie et al., 2022). Additionally, *Camellia oleifera* oil contains active substances such as squalene and sterols, which have immunomodulatory effects (Fig. 6) (Fisher et al., 2023).

7. Conclusions

It is well-known that camellia oil has over 85% unsaturated fatty acids which are benificial to human health. Thus, it is a outstanding nutritional edible oil that meets human needs. Substances with rich antioxidant activity in camellia oil, such as polyphenol saponins, squalene, and sterols, hold great promise in cosmetics research. Therefore, the use of camellia oil as a raw material to develop high-value cosmetic products could contribute to human health and become a significant competitive advantage in cosmetics industry, offering considerable possibilities and practical significance.

There are traditional and cutting-edge extraction methods of camellia oil which have their own strengths and weaknesses. On our point of view, the ultrasonic assisted and microwave-assisted are low-cost and chemical residues free. Thus, the scale-up of ultrasonic assisted and microwave-assisted extration are proposed, in the same time, the couple of ultrasonic assisted and microwave-assisted has great potential in camellia oil production. Nevertheless, according to reserve high value bioactive components in maximum such as vitamine E, polyphenol, sterol, the supercritical fluid extraction, subcritical fluid extraction and enzymatic extraction are recommended.

While previous studies have shown the promising potential of camellia oil in medical care, there is a significant research gap on the molecular mechanisms underlying its biological effects. In this review, we compiled the recent articles of underlying molecular mechanism of camellia oil which are related to the antioxidant, anti-inflammatory, anticancer effects and so on closely asscociated with our health care. To sum up, the NF-κB signaling pathway is involving in anti-inflammatory action and immunoregulatory activity, suggestting NF-κB is a crucial therapeutic target for the bioactive components in *Camellia oleifera* oil. This review laid a foundation for the application of bioactive components in *Camellia oleifera* oil both for comestic and medicinal use.

CRediT authorship contribution statement

Peiju Qin: Writing—, Writing – original draft, preparation, Drawing. **Junjun Shen:** Conceptualization, Writing – review & editing, Funding acquisition. **Jeigen Wei:** Writing – original draft, preparation, Drawing. **Yuqi Chen:** Drawing, All authors have read and agreed to the published version of the manuscript.

Declaration of competing interest

Declaration of competing interest The authors have confirmed that there are no conflicts of interest associated with this publication.

Data availability

No data was used for the research described in the article.

Acknowledgments:

This research was supported by Key Project of the Education Department of Hunan Province (no. 20A529).

Abbreviations:

GZY-1	Ganzhouyou-1
YKX-2	Yuekexia-2
TRP-2	tyrosinase-related protein-2
Ge-132	bis-(carboxyethylgermanium) sesquioxide

COG2a the anticancer potential of a new glycoprotein
NF-κB nuclear translocation of nuclear factor-kappa B
MAPK Mitogen-activated protein kinases
GC/MS Gas chromatography-mass spectrometry

References

Ahangari, H., King, J.W., Ehsani, A., Yousefi, M., 2021. Supercritical fluid extraction of seed oils–A short review of current trends. Trends Food Sci. Technol. 111, 249–260. https://doi.org/10.1016/j.tifs.2021.02.066.

Ahsan, H., Ahad, A., Siddiqui, W.A., 2015. A review of characterization of tocotrienols from plant oils and foods. Journal of chemical biology 8, 45–59. https://doi.org/10.1007/s1215401401278.

Angoy, A., Ginies, C., Goupy, P., Bornard, I., Ginisty, P., Sommier, A., et al., 2020. Development of a green innovative semi-industrial scale pilot combined microwave heating and centrifugal force to extract essential oils and phenolic compounds from orange peels. Innovat. Food Sci. Emerg. Technol. 61, 102338 https://doi.org/10.1016/j.ifset.2020.102338.

Blanco-Vaca, F., Cedó, L., Julve, J., 2019. Phytosterols in cancer: from molecular mechanisms to preventive and therapeutic potentials. Curr. Med. Chem. 26 (37), 6735–6749. https://doi.org/10.2174/0929867325666180607093111.

Cao, Y., Yao, X., Ren, H., et al., 2017. Determination of fatty acid composition and metallic element content of four Camellia species used for edible oil extraction in China. Journal of Consumer Protection and Food Safety 12, 165–169. https://doi.org/10.1007/s0000301711042.

Cayuela, J.A., García, J.F., 2018. Nondestructive measurement of squalene in olive oil by near infrared spectroscopy. Lwt 88, 103–108. https://doi.org/10.1016/j.lwt.20117.09.0417.

Cedó, L., Farràs, M., Lee-Rueckert, M., Escolà-Gil, J.C., 2019. Molecular insights into the mechanisms underlying the cholesterol-lowering effects of phytosterols. Curr. Med. Chem. 26 (37), 6704–6723. https://doi.org/10.2174/0929867326666190822154701.

Chaikul, P., Sripisut, T., Chanpirom, S., Sathirachawan, K., Ditthawuthikul, N., 2017. Melanogenesis inhibitory and antioxidant effects of camellia oleifera seed oil. Adv. Pharmaceut. Bull. 7 (3), 473–477, 10.15171./apb.2017.057.

Chang, M., Qiu, F.C., Lan, N., Zhang, T., Guo, X., Jin, Q.Z., et al., 2020. Analysis of phytochemical composition of camellia oleifera oil and evaluation of its anti-inflammatory effect in lipopolysaccharide-stimulated RAW 264.7 macrophages. Lipids 55 (4). https://doi.org/10.1002/lipd.12241.

Che, X.N., Ding, Z.Y., Xu, K.J., Cao, Y.P., Pei, C.L., Tong, Y., 2017. Research progress on efficacy, application and separation technology of tocopherol monomer. ChinaOilsandFats 42 (12), 103–107. https://doi.org/10.11949/j.issn.0438-1157.20161437.

Chemat, F., Vian, M.A., Ravi, H.K., Khadhraoui, B., Hilali, S., Perino, S., Tixier, A.S.F., 2019. Review of alternative solvents for green extraction of food and natural products: panorama, principles, applications and prospects. Molecules 24 (16). https://doi.org/10.3390/molecules24163007.

Chen, J.H., Liau, B.C., Jong, T.T., Chang, C.M.J., 2009. Extraction and purification of flavanone glycosides and kaempferol glycosides from defatted Camellia oleifera seeds by salting-out using hydrophilic isopropanol. Sep. Purif. Technol. 67, 31–37. https://doi.org/10.1016/j.seppur.2009.02.020.

Chen, Y.J., Wang, L.L., Chen, X.P., et al., 2011. Determination of oil content and fatty acid composition of Camellia oleifera seeds in Hechi, Baise and Wuzhou, Guangxi. Food Sci. (N. Y.) 32 (8), 172–176.

Chen, L., Chen, J., Xu, H., 2013. Sasanquasaponin from Camellia oleifera Abel. induces cell cycle arrest and apoptosis in human breast cancer MCF-7 cells. Fitoterapia 84, 123–129. https://doi.org/10.1016/j.fitote.2012.11.009.

Cheok, C.Y., Salman, H.A.K., Sulaiman, R., 2014. Extraction and quantification of saponins: a review. Food Res. Int. 59, 16–40. https://doi.org/10.1016/j.foodres.2014.01.057.

Chew, S.C., 2020. Cold-pressed rapeseed (Brassica napus) oil: chemistry and functionality. Food Res. Int. 131, 108997 https://doi.org/10.1016/j.foodres.2020.1089997.

Chu, Z., Han, S., Luo, Y., Zhou, Y., Zhu, L., Luo, F., 2023. Targeting gut-brain axis by dietary flavonoids ameliorate aging-related cognition decline: evidences and mechanisms. Crit. Rev. Food Sci. Nutr. 1–22.

Di, T.M., Yang, S.L., Du, F.Y., et al., 2017. Cytotoxic and hypoglycemic activity of triterpenoid saponins from Camellia oleifera Abel. seed pomace. Molecules 22 (10), 1562. https://doi.org/10.3390/molecules22101562.

Du, Z.X., Zhang, C.G., Wan, D.J., 2015. Optimization of ultrasonic assisted ethanol extraction of tea saponin. Chemical and Biological Engineering 32 (3), 56–59. https://doi.org/10.1016/j.jarmap.2022.100443.

Fang, X.Z., Du, M.H., Luo, F., Jin, Y.F., 2015. Physicochemical properties and lipid composition of camellia seed oil (Camellia oleifera Abel.) extracted using different methods. Food Sci. Technol. Res. 21 (6), 779–785. https://doi.org/10.3136/fstr.21.779.

Fang, X.Z., Fei, X.Q., Sun, H., Jin, Y.F., 2016. Aqueous enzymatic extraction and demulsification of camellia seed oil (Camellia oleifera Abel.) and the oil's physicochemical properties. Eur. J. Lipid Sci. Technol. 118 (2), 244–251. https://doi.org/10.1002/ejlt.201400582.

Feng, Q.Y., Song, N., Huang, H.X., et al., 2016. Advances in medicinal research of Camellia oil. Chinese Journal of Experimental Prescriptions 22 (10), 215–220. https://doi.org/10.13422/j.cnki.syfjx.2016100215.

Feng, J., Ma, Y.L., Sun, P., Thakur, K., Wang, S., Zhang, J.G., Wei, Z.J., 2021. Purification and characterisation of α-glucosidase inhibitory peptides from defatted camellia seed cake. International Journal of Food Science & Technology 56 (1), 138–147. https://doi.org/10.1111/ijfs.14613.

Feng, J., Zheng, Y., Guo, M., et al., 2023. Oxidative stress, the blood-brain barrier and neurodegenerative diseases: the critical beneficial role of dietary antioxidants. Acta Pharm. Sin. B 13 (10), 3988–4024, 10.101.6/j.apsb.2023.07.010.

Fisher, K.J., Kinsey, R., Mohamath, R., Phan, T., Liang, H., Orr, M.T., et al., 2023. Semi-synthetic terpenoids with differential adjuvant properties as sustainable replacements for shark squalene in vaccine emulsions. npj Vaccines 8 (1), 14. https://doi.org/10.1038/s41541-023-00608-y.

Fu, H.Z., Wan, K.H., Yan, Q.W., et al., 2018. Cytotoxic triterpenoid saponins from the defatted seeds of Camellia oleifera Abel. J. Asian Nat. Prod. Res. 20 (5), 412–422. https://doi.org/10.1080/10286020.2017.1343822.

Gao, J., Ma, Li, Ma, Jie, Xia, S.T., Gong, S.M., Yin, Y.L., Chen, Y.Z., 2022. Camellia (camellia oleifera abel.) seed oil regulating of metabolic phenotype and alleviates dyslipidemia in high fat-fed mice through serum branch-chain amino acids. Nutrients 14 (12). https://doi.org/10.3390/nu14122424.

Guo, N., Tong, T., Ren, N., Tu, Y., Li, B., 2018. Saponins from seeds of genus camellia: phytochemistry and bioactivity. Phytochemistry 149, 42–55. https://doi.org/10.1017/j.phytochen.2018.02.002.

Guo, L., Guo, Y., Wu, P., et al., 2020. Camellia oil lowering blood pressure in spontaneously hypertension rats. J. Funct.Foods 70, 103915. https://doi.org/10.1016/j.jff.2020.103915.

Guo, Y.X., Jia, Z., Wan, L.T., Cao, J., Fang, Y.J., Zhang, W.M., 2023. Effects of refining process on Camellia vietnamensis oil: phytochemical composition, antioxidant capacity, and anti-inflammatory activity in THP-1 macrophages. Food Biosci. 52 https://doi.org/10.1016/j.fbio.2023.102440.

Han, S., Luo, Y., Liu, B., Guo, T., Qin, D., Luo, F., 2023. Dietary flavonoids prevent diabetes through epigenetic regulation: advance and challenge. Crit. Rev. Food Sci. Nutr. 63 (33), 11925–11941.

He, J., Wu, Z.Y., Zhang, S., Zhou, Y., Zhao, F., Peng, Z.Q., Hu, Z.W., 2014. Optimization of microwave-assisted extraction of tea saponin and its application on cleaning of historic silks. J. Surfactants Deterg. 17, 919–928. https://doi.org/10.1007/s11743-013-1523-8.

Hu, L., Fang, X., Du, M., Zhang, J., 2015. Anti-fatigue effect of blended camellia oleifera abel tea oil and Ge-132 in mice. Food Nutr. Sci. 6 (15), 1479. https://doi.org/10.4236/FNS.2015.615152.

Hu, Y., Ma, C., Yang, R., Guo, S., Wang, T., Liu, J., 2023. Impact of molecular interactions between hydrophilic phytosterol glycosyl derivatives and bile salts on the micellar solubility of cholesterol. Food Res. Int. 167, 112642 https://doi.org/10.1016/j.foodres.2023.112642.

Huang, S., Wu, S.X., Tan, C.B., 2014. Research on the process of microwave pretreatment-supercritical CO_2 extraction of high-quality tea seed oil. Science and Technology of Food Industry 35 (24), 253–257+263. https://doi.org/10.13386/j.issn1002-0306.2014.24.046.

Huang, T., Jiang, J., Cao, Y., Huang, J., Zhang, F., Cui, G., 2023. Camellia oil (Camellia oleifera Abel.) treatment improves high-fat diet-induced atherosclerosis in apolipoprotein E (ApoE)−/− mice. Bioscience of Microbiota, Food and Health 42 (1), 56–64. https://doi.org/10.12938/bmfh.2022-005.

Ibrahim, N.I., Fairus, S., Zulfarina, M.S., Naina Mohamed, I., 2020. The efficacy of squalene in cardiovascular disease risk-a systematic review. Nutrients 12 (2), 414. https://doi.org/10.3390/nu1220414.

Javed, M., Belwal, T., Huang, H., Xu, Y., Ettoumi, F.E., Li, L., et al., 2022. Generation and stabilization of CO2 nanobubbles using surfactants for extraction of polyphenols from Camellia oleifera shells. J. Food Sci. 87 (9), 4027–4039. https://doi.org/10.1111/1750-3841.16272.

Jia, L.Y., Wu, X.J., Gao, Y., Rankin, G.O., Pigliacampi, A., Bucur, H., et al., 2017. Inhibitory effects of total triterpenoid saponins isolated from the seeds of the tea plant (Camellia sinensis) on human ovarian cancer cells. Molecules 22 (10), 1649. https://doi.org/10.3390/molecules22101649.

Jiamphun, S., Chaiyana, W., 2022. Enhanced antioxidant, hyaluronidase, and collagenase inhibitory activities of glutinous rice husk extract by aqueous enzymatic extraction. Molecules 27 (10), 3317. https://doi.org/10.3390/molecules27103317.

Jiang, N., Hu, Y.D., Li, X., 2022. Research progress on biological activity and application of tea saponin in processing residues of Camellia oleifera. Packaging Journal 14 (4), 42–49. https://doi.org/10.3969/j.issn.1674-7100.2022.04.006.

Koubaa, M., Mhemdi, H., Barba, F.J., Roohinejad, S., Greiner, R., Vorobiev, E., 2016. Oilseed treatment by ultrasounds and microwaves to improve oil yield and quality: an overview. Food Res. Int. 85, 59–66. https://doi.org/10.10116/j.foodres.2016.04.007.

Lee, W.T., Tung, Y.T., Wu, C.C., et al., 2018. Camellia oil (Camellia oleifera Abel.) modifies the composition of gut microbiota and alleviates acetic acid-induced colitis in rats. J. Agric. Food Chem. 66 (28), 7384–7392. https://doi.org/10.1021/acs.jafc.8b02166.

Lei, X., Liu, Q., Cao, Z., et al., 2020. Camellia oil (Camellia oleifera Abel.) attenuates CCl 4-induced liver fibrosis via suppressing hepatocyte apoptosis in mice. Food Funct. 11 (5), 4582–4590. https://doi.org/10.1039/C9FO02258A.

Li, T., Zhang, H., Wu, C., 2014. Screening of antioxidant and antitumor activities of major ingredients from defatted Camellia oleifera seeds. Food Sci. Biotechnol. 23, 873–880. https://doi.org/10.1007/s10068-014-0117-1.

Li, Z.X., Jin, Q.Z., Ye, X.F., Huang, J.H., Liu, R.J., Wang, X.G., 2015. Impact of extraction process on quality of oil-tea camellia seed oil. China Oils Fats 40 (4), 47–51.

Li, T., Meng, X., Wu, C., et al., 2019. Anticancer activity of a novel glycoprotein from Camellia oleifera Abel seeds against hepatic carcinoma in vitro and in vivo. Int. J. Biol. Macromol. 136, 284–295. https://doi.org/10.1016/j.ijbiomac.2019.06.054.

Li, Z., Wang, Z.C., Zhang, L.B., Zhu, H.L., 2020. Pharmacological activities of components contained in camellia oil and camellia oil cake and their applications in various industries. Current Traditional Medicine 6 (2), 86–105. https://doi.org/10.2174/2215083805666191018163235.

Li, G., Ma, L., Yan, Z., Zhu, Q., Cai, J., Wang, S., et al., 2022. Extraction of oils and phytochemicals from Camellia oleifera seeds: trends, challenges, and innovations. Processes 10 (8), 1489. https://doi.org/10.3390/pr10081489.

Liang, F., Guo, H., Zhou, Y., 2016. Quality analysis and comparison of Camellia oleifera seed oil extracted by four methods. Food Science and Technology (China) 41 (5), 196–200.

Liau, B.C., Ponnusamy, V.K., Lee, M.R., Jong, T.T., Chen, J.H., 2017. Development of pressurized hot water extraction for five flavonoid glycosides from defatted Camellia oleifera seeds (byproducts). Ind. Crop. Prod. 95, 296–304. https://doi.org/10.1016/j.indcrop.2016.10.034.

Liu, X., Jia, L., Gao, Y., Li, B., Tu, Y., 2014. Anti-inflammatory activity of total flavonoids from seeds of Camellia oleifera Abel. Acta Biochim. Biophys. Sin. 46 (10), 920–922. https://doi.org/10.1093/abbs/gmu071.

Liu, Z.X., Chen, Y., Luo, X.H., 2014. Research progress of active components of Camellia oil in medicine. Journal of Jinhua Vocational and Technical College 14 (3), 77–81. https://doi.org/10.3969/j.issn.1671-3699.2014.03.020.

Liu, Y., Xiao, X., Ji, L., et al., 2020. Camellia cake extracts reduce burn injury through suppressing inflammatory responses and enhancing collagen synthesis. Food Nutr. Res. 64 https://doi.org/10.29219/fnr.v64.3782.

Liu, L., Feng, S., Chen, T., Zhou, L., Yuan, M., Liao, J., et al., 2021. Quality assessment of camellia oleifera oil cultivated in Southwest China. Separations 8 (9), 144. https://doi.org/10.3390/separation8090/separations8090144.

Long, L., Gao, C., Qiu, J., Yang, L., Wei, H., Zhou, Y., 2022. Fatty acids and nutritional components of the seed oil from Wangmo red ball Camellia oleifera grown in the low-heat valley of Guizhou, China. Sci. Rep. 12 (1), 16554 https://doi.org/10.1038/s41598-022-20576-y.

Lou-Bonafonte, J.M., Martínez-Beamonte, R., Sanclemente, T., Surra, J.C., Herrera-Marcos, L.V., Sanchez-Marco, J., et al., 2018. Current insights into the biological action of squalene. Mol. Nutr. Food Res. 62 (15), 1800136 https://doi.org/10.1002/mnfr.201800136.

Luan, F., Zeng, J., Yang, Y., He, X., Wang, B., Gao, Y., Zeng, N., 2020. Recent advances in Camellia oleifera Abel: a review of nutritional constituents, biofunctional properties, and potential industrial applications. J. Funct.Foods 75, 104242. https://doi.org/10.1002/mnfr.201800136.

Lv, M., Wu, W., 2019. Development of a new aqueous procedure for efficiently extracting high quality Camellia oleifera oil. Ind. Crop. Prod. 138, 11583 https://doi.org/10.1016/j.indcrop.2019.111583.

Lv, J., Sun, F., Geng, Y., 2014. Determination of four functional ingredients in camellia oil. Journal of Food Safety and Quality 5 (6), 1641–1646. https://doi.org/10.19812/j.cnki.jfsq11-5956/ts.2014.06.012.

Malheiro, R., Casal, S., Lamas, H., et al., 2012. Can tea extracts protect extra virgin olive oil from oxidation during microwave heating? Food Res. Int. 48 (1), 148–154. https://doi.org/10.1016/j.foodres.2012.03.005.

Meng, X.H., Li, N., Zhu, H.T., Wang, D., Yang, C.R., Zhang, Y.J., 2018a. Plant resources, chemical constituents, and bioactivities of tea plants from the genus Camellia section Thea. J. Agric. Food Chem. 67 (19), 5318–5349. https://doi.org/10.1021/acs.jafc.8b05037.

Meng, X., Ge, H., Ye, Q., Peng, L., Wang, Z., Jiang, L., 2018b. Efficient and response surface optimized aqueous enzymatic extraction of Camellia oleifera (tea seed) oil facilitated by concurrent calcium chloride addition. J. Am. Oil Chem. Soc. 95 (1), 29–37. https://doi.org/10.1002/aocs.12009.

Miao, J., Che, K., Xi, R., et al., 2013. Characterization and benzo [a] pyrene content analysis of camellia seed oil extracted by a novel subcritical fluid extraction. J. Am. Oil Chem. Soc. 90 (10), 1503–1508. https://doi.org/10.1007/s11746-013-2293-1.

Miao, Y.P., Chen, A.Y., Xia, Z.G., etc, 2015. Protective effect of squalene on acute alcoholic liver injury in mice. Food Industry Technology 36 (16), 364–365 + 377. https://doi.org/10.1016/j.ejphar.2008.02.059.

Mohamed, M.A., Ibrahim, M.T., Abdel-Azim, N.S., El-Missiry, M.M., 2021. Chemical and biological studies on Moringa oleifera L. cultivated in Egypt. Egypt. Pharm. J. 20 (1), 33–41. https://doi.org/10.4103/epj_37_20.

Mumtaz, M.Z., Kausar, F., Hassan, M., Javaid, S., Malik, A., 2021. Anticancer activities of phenolic compounds from Moringa oleifera leaves: in vitro and in silico mechanistic study. Beni-Suef University Journal of Basic and Applied Sciences 10, 1–11. https://doi.org/10.1186/s43088-021-00101-2.

Mwaurah, P.W., Kumar, S., Kumar, N., et al., 2020. Novel oil extraction technologies: process conditions, quality parameters, and optimization. Compr. Rev. Food Sci. Food Saf. 19 (1), 3–20. https://doi.org/10.1111/1541-4337.12507.

Ni, Z., Tang, F., Yu, Q., et al., 2016. Determination of trace elements in camellia oil by vortex-assisted extraction followed by inductively coupled plasma mass spectrometry. Food Anal. Methods 9, 1134–1141. https://doi.org/10.1016/j.jbiosc.2019.05.010.

Nowicka, B., Kruk, J., 2017. Vitamin E-occurrence, biosynthesis by plants and functions in human nutrition. Mini reviews in medicinal chemistry 17 (12), 1039–1052. https://doi.org/10.2174/1389557516666160725094819.

Peng, L., Ye, Q., Liu, X.Y., Liu, S.L., Meng, X.H., 2019. Optimization of aqueous enzymatic method for Camellia sinensis oil extraction and reuse of enzymes in the process. J. Biosci. Bioeng. 128 (6), 716–722. https://doi.org/10.1016/j.jbiosc.2019.05.010.

Qi, S., Chen, H., Liu, Y., Wang, W., Shen, L., Wang, Y., 2015. Evaluation of glycidyl fatty acid ester levels in camellia oil with different refining degrees. Int. J. Food Prop. 18 (5), 978–985. https://doi.org/10.1080/10942912.2013.858351.

Rahayu, I., Timotius, K.H., 2022. Phytochemical Analysis, Antimutagenic and antiviral activity of Moringa oleifera L. leaf infusion: in Vitro and in silico studies. Molecules 27 (13), 4017. https://doi.org/10.3390/molecules27134017.

Sahari, M.A., Amooi, M., 2013. Tea seed oil: extraction, compositions, applications, functional andantioxidant properties. Acad. J. Med. Plants 1 (4), 68–79, 101340/RG.2.1.3147.8644.

Sánchez-Fidalgo, S., Villegas, I., Rosillo, M.Á., Aparicio-Soto, M., de la Lastra, C.A., 2015. Dietary squalene supplementation improves DSS-induced acute colitis by downregulating p38 MAPK and NFkB signaling pathways. Mol. Nutr. Food Res. 59 (2), 284–292. https://doi.org/10.1002/mnfr.201400518.

Santanatoglia, A., Nzekoue, F.K., Sagratini, G., Ricciutelli, M., Vittori, S., Caprioli, G., 2023. Development and application of a novel analytical method for the determination of 8 plant sterols/stanols in 22 legumes samples. J. Food Compos. Anal. 118, 105195 https://doi.org/10.1016/j.jfca.2023.105195.

Sato, N., Li, W., Tsubaki, M., et al., 2017. Flavonoid glycosides from Japanese Camellia oil cakes and their inhibitory activity against advanced glycation end-products formation. J. Funct.Foods 35, 159–165. https://doi.org/10.1016/j.jff.2017.05.043.

Semwal, R., Joshi, S.K., Semwal, R.B., Semwal, D.K., 2021. Health benefits and limitations of rutin-A natural flavonoid with high nutraceutical value. Phytochem. Lett. 46, 119–128. https://doi.org/10.1016/j.phytol.2021.10.006.

Shen, J., Liu, Y., Wang, X., Bai, J., Lin, L., Luo, F., Zhong, H., 2023. A comprehensive review of health-benefiting components in rapeseed oil. Nutrients 15 (4), 999. https://doi.org/10.3390/nu15040999.

Shi, T., Wu, G., Jin, Q., Wang, X., 2020. Camellia oil authentication: a comparative analysis and recent analytical techniques developed for its assessment. A review. Trends in food science & technology 97, 88–99. https://doi.org/10.1080/1.0408398.20161225666.

Song, Y., Han, Y., Wen, J.T., Li, Y.M., Shi, L.Y., Lu, X., et al., 2018. Research progress of saponins from Camellia and their pharmacological activities. Journal of Dalian University 39 (6), 41–52. https://doi.org/10.13305/j.cnki.jjts.2011.05.016.

Su, M.H., Shih, M.C., Lin, K.H., 2014. Chemical composition of seed oils in native Taiwanese Camellia species. Food Chem. 156, 369–373. https://doi.org/10.1016/j.foodchem.2014.02.016.

Tang, W., Chen, Y.Z., Chen, L.S., Wang, R., 2017. Development status and countermeasures of oil tea industry in Hunan Province. Green Science and Technology 15, 208–210+212. https://doi.org/10.16663/j.cnki.lskj.2017.15.089.

Tu, P.S., Tung, Y.T., Lee, W.T., et al., 2017. Protective effect of Camellia oil (Camellia oleifera Abel.) against ethanol-induced acute oxidative injury of the gastric mucosa in mice. J. Agric. Food Chem. 65 (24), 4932–4941. https://doi.org/10.1021/acs.jafc.7b01135.

Wang, X.Q., Liang, X.Q., Zhao, J., Huang, B.B., 2014. Cultivar characterization of tea seed oils by their active components and antioxidant capacity. J. Am. Oil Chem. Soc. 91, 629–639. https://doi.org/10.1007/s11746-013-2.397-7.

Wang, X., Zeng, Q., Verardo, V., et al., 2017a. Fatty acid and sterol composition of tea seed oils: their comparison by the "FancyTiles" approach. Food Chem. 233, 302–310. https://doi.org/10.1016/j.foodchem.2017.04.110.

Wang, X., Zeng, Q., del Mar Contreras, M., Wang, L., 2017b. Profiling and quantification of phenolic compounds in Camellia seed oils: natural tea polyphenols in vegetable oil. Food Res. Int. 102, 184–194. https://doi.org/10.1016/foodres.2017.09.089.

Wang, Y., Ke, L., Yang, Q., Peng, Y., Hu, Y., Dai, L., et al., 2019. Biorefinery process for production of bioactive compounds and bio-oil from Camellia oleifera shell. Int. J. Agric. Biol. Eng. 12 (5), 190–194. https://doi.org/10.25165/j.ijabe.20191205.4593.

Wang, L., Ahmad, S., Wang, X., Li, H., Luo, Y., 2021. Comparison of antioxidant and antibacterial activities of camellia oil from Hainan with camellia oil from Guangxi, olive oil, and peanut oil. Front. Nutr. 8, 667744 https://doi.org/10.3389/fnut.2021.667744.

Wu, J.B., Zhou, L., Hu, C.R., He, D.P., 2015. Aqueous enzymatic extraction of Camellia oleifera seed oil and protein simultaneously. Grains and Fats (China) 28 (9), 58–61. https://doi.org/10.1002/ejlt.201400582.

Wu, H., Li, C., Li, Z., Liu, R., Zhang, A., Xiao, Z., et al., 2018. Simultaneous extraction of oil and tea saponin from Camellia oleifera Abel. seeds under subcritical water conditions. Fuel Process. Technol. 174, 88–94. https://doi.org/10.1016/j.fuproc.2018.02.014.

Wu, Z., Tan, X., Zhou, J., Yuan, J., Yang, G., Li, Z., et al., 2022. Discovery of new triterpenoids extracted from camellia oleifera seed cake and the molecular mechanism underlying their antitumor activity. Antioxidants 12 (1), 7. https://doi.org/10.3390/antiox12010007.

Xiao, H., Yao, Z., Peng, Q., Ni, F., Sun, Y., Zhang, C.X., Zhong, Z.X., 2016. Extraction of squalene from camellia oil by silver ion complexation. Separation and Purification Technology 169, 196–201. https://doi.org/10.1016/seppur.2016.05.041.

Xiao, X., He, L., Chen, Y., Wu, L., Wang, L., Liu, Z., 2017. Anti-inflammatory and antioxidative effects of Camellia oleifera Abel components. Future Med. Chem. 9 (17), 2069–2079. https://doi.org/10.4155/fmc-2017-0109.

Xiao, P., Liu, H., Wang, D., Tang, W., Yang, H., Wang, C., et al., 2020. Assessment of genetic diversity in Camellia oleifera Abel. accessions using inter-simple sequence repeat (ISSR) and start codon targeted (SCoT) polymorphic markers. Genet. Resour. Crop Evol. 67, 1115–1124. https://doi.org/10.1007/s10722-020-00924-5.

Xie, X.M., He, J.B., Xiao, N., 2015. Physiological function of phytosterol and its application. Animal Husbandry and Feed Science 7 (2), 67. https://doi.org/10.19578/j.cnki.ahfs.2015.02.002.

Xie, B., Yang, R.J., Gu, J., 2016. Effect of crushing degree of camellia seed on oil extraction by aqueous enzymatic method. Food and machinery 32 (3), 174–177. https://doi.org/10.13652/j.issn.1003-5788.2016.03.038.

Xie, C., Lin, X., Hu, J., Wang, S., Wu, J., Xiong, W., Wu, L., 2022. The polysaccharide from Camellia oleifera fruit shell enhances immune responses via activating MAPKs

and NF-κB signaling pathways in RAW264. 7 macrophages. Food Nutr. Res. 66 https://doi.org/10.29219/fnr.v66.8963.
Yang, C., Liu, X., Chen, Z., Lin, Y., Wang, S., 2016. Comparison of oil content and fatty acid profile of ten new Camellia oleifera cultivars. Journal of lipids 2016. https://doi.org/10.1155/2016/3982486.
Yang, C.C., Yao, X.H., Feng, J.F., et al., 2022. Analysis of fruit traits and fatty acid composition of new strains of Camellia oleifera in Hainan. J. Jiangxi Agric. Univ. 44 (3), 614–625. https://doi.org/10.13836/j.jjau.2022062.
Ye, Y., Xing, H., Li, Y., 2014. Nanoencapsulation of the sasanquasaponin from Camellia oleifera, its photo responsiveness and neuroprotective effects. Int. J. Nanomed. 4475–4484. https://doi.org/10.2147/IJN.S64313.
Ye, M., Zhou, H., Hao, J., Chen, T., He, Z., Wu, F., Liu, X., 2021. Microwave pretreatment on microstructure, characteristic compounds and oxidative stability of Camellia seeds. Ind. Crop. Prod. 161, 113193 https://doi.org/10.1016/j.indcrop.2020.113193.
Yingngam, B., Navabhatra, A., Brantner, A., 2021. Increasing the essential oil yield from Shorea roxburghii inflorescences using an eco-friendly solvent-free microwave extraction method for fragrance applications. Journal of Applied Research on Medicinal and Aromatic Plants 24, 100332 j.jarmap.2021.100332.
Yu, J., Yan, H., Wu, Y., Wang, Y., Xia, P., 2022. Quality evaluation of the oil of camellia spp. Foods 11 (15), 2221. https://doi.org/10.3390/foods11152221.
Yu, Z., Wu, X., He, J., 2022. Study on the antifungal activity and mechanism of tea saponin from Camellia oleifera cake. European Food Research and Technology 1–13. https://doi.org/10.1007/s00217-021-03929-1.
Yuan, J., Wang, C., Chen, H., Zhou, H., Ye, J., 2013. Prediction of fatty acid composition in Camellia oleifera oil by near infrared transmittance spectroscopy (NITS). Food Chem. 138 (2–3), 1657–1662. https://doi.org/10.1016/j.foodchem.2012.11.096.
Yusoff, M.M., Gordon, M.H., Niranjan, K., 2015. Aqueous enzyme assisted oil extraction from oilseeds and emulsion de-emulsifying methods: a review. Trends Food Sci. Technol. 41 (1), 60–82. https://doi.org/10.1016/j.tifs.2014.09.003.
Zeng, W., Endo, Y., 2019. Effects of cultivars and geography in China on the lipid characteristics of Camellia oleifera seeds. J. Oleo Sci. 68 (11), 1051–1061. https://doi.org/10.5650/jos.ess19154.
Zhang, S., Li, X., 2018. Hypoglycemic activity in vitro of polysaccharides from Camellia oleifera Abel. seed cake. Int. J. Biol. Macromol. 115, 811–819. https://doi.org/10.1016/j.ijbiomac.2018.04.054.
Zhang, H., Cai, L., Zhu, L.F., et al., 2011. Analysis of fatty acid composition in camellia oil. Shanxi Forestry Science and Technology (5), 1–3 j.issn.1001-2117.2011.05.001.
Zhang, X.F., Yang, S.L., Han, Y.Y., Zhao, L., Lu, G.L., Xia, T., Gao, L.P., 2014. Qualitative and quantitative analysis of triterpene saponins from tea seed pomace (Camellia oleifera abel) and their activities against bacteria and fungi. Molecules 19 (6), 7568–7580. https://doi.org/10.3390/molecules19067568.
Zhang, W.R., Wu, T.Y., Yang, M.H., 2015. Screening and culture medium optimization of polyphenol oxidase producing-fungi from endophytes of tea plant (Camellia sinensis). J. Tea Sci. 35 (3), 271–280. https://doi.org/10.13305/j.cnki.jts.2015.03.010.
Zhang, T., Zuo, X.Z., Lai, Y., 2016. Screening of endophytic fungi with polyphenols from Camellia oleifera. Agriculture and Technology 36 (22), 36–37+54.
Zhang, S., Pan, Y.G., Zheng, L., Yang, Y., Zheng, X., Ai, B., 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 Sci. Nutr. 7 (3), 1004–1016. https://doi.org/10.1002/fsn3.924.
Zhang, F., Zhu, F., Chen, B., Su, E., Chen, Y., Cao, F., 2022. Composition, bioactive substances, extraction technologies and the influences on characteristics of Camellia oleifera oil: a review. Food Res. Int. 156, 111159 https://doi.org/10.5650/jos.ess19154.
Zhang, X., Ma, H., Quaisie, J., Gu, C., Guo, L., Liu, D., et al., 2022. Tea saponin extracted from seed pomace of Camellia oleifera Abel ameliorates DNCB-induced atopic dermatitis-like symptoms in BALB/c mice. J. Funct.Foods 91, 105001, 10/1016/j.jff.2022.105001.
Zhao, Y., Fan, Y.Y., Yu, W.G., Wang, J., Lu, W., Song, X.Q., 2019. Ultrasound-enhanced subcritical fluid extraction of essential oil from Nymphaea alba var and its antioxidant activity. J. AOAC Int. 102 (5), 1448–1454. https://doi.org/10.5740/jaoacint.18-0337.
Zhao, Y., Su, R., Zhang, W., et al., 2020. Antibacterial activity of tea saponin from Camellia oleifera shell by novel extraction method. Industrial crops and products 153, 112604. https://doi.org/10.1016/j.indcrop.2020.112604.
Zhou, H., Wang, C.Z., Ye, J.Z., Chen, H.X., 2014. New triterpene saponins from the seed cake of camellia oleifera and their cytotoxic activity. Phytochem. Lett. 8, 46–51. https://doi.org/10.1016/j.phytol.2014.01.006.
Zhou, Y., Guo, H., Xiang, J., 2016. Effects of composite enzyme on extracting oil-camellia seed oil by aqueous enzymatic method. Food Sci. Technol. Res. 41 (2), 211–215. https://doi.org/10.1002/aocs.12009.
Zhou, D., Shi, Q., Pan, J., Liu, M., Long, Y., Ge, F., 2019. Effectively improve the quality of camellia oil by the combination of supercritical fluid extraction and molecular distillation (SFE-MD). Lwt 110, 175–181. https://doi.org/10.1016/j.lwt.2019.04.075.
Zhou, L., Luo, S., Li, J., Zhou, Y., Wang, X., Kong, Q., et al., 2021. Optimization of the extraction of polysaccharides from the shells of Camellia oleifera and evaluation on the antioxidant potential in vitro and in vivo. J. Funct.Foods 86, 104678. https://doi.org/10.1016/j.jff.2021.104678.
Zong, J., Wang, R., Bao, G., et al., 2015. Novel triterpenoid saponins from residual seed cake of Camellia oleifera Abel. show anti-proliferative activity against tumor cells. Fitoterapia 104, 7–13. https://doi.org/10.1016/j.fitote.2015.05.001.
Zong, J., Wang, D., Jiao, W., et al., 2016. Oleiferasaponin C 6 from the seeds of Camellia oleifera Abel.: a novel compound inhibits proliferation through inducing cell-cycle arrest and apoptosis on human cancer cell lines in vitro. Rsc Advances 6 (94), 91386–91393. https://doi.org/10.1039/c6ra14467e.
Zong, Y., Xiong, D.L., Li, Y., Wang, L.Q., Cao, X.W., Ouyang, S.B., Yang, J.B., 2019. Ultrasonic - methanol extraction of tea saponin technology research. Journal of jiangxi university of science and technology 40 (1), 35–39. https://doi.org/10.13265/j.cnki.jxlgdxxb.2019.01.007.