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Occurrence of fatty acids in *Camellia* genus: Extractions technologies and potential applications: A review

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ABSTRACT

The Camellia genus (Theaceae) comprises more than 200 species, including the most famous *Camellia sinensis* (L.) Kuntze, *Camellia oleifera* Abel, and *Camellia japonica* (L.). The commercial interest in these plants linked to their seed fatty acid content increased in the last decades due to their quality and health-enhancing properties, which significantly depend on different aspects such as environmental conditions. Nowadays, the traditional extraction methods of fatty acids from camellias include mechanical press extraction and solvent extraction, which have a high environmental impact. Therefore, it is essential to develop extraction techniques to achieve the maximum lipid yield with the minimum environmental impact and cost. These innovative methods include enzymatic extraction, supercritical fluid extraction (SFE), microwave-assisted extraction (MAE) and ultrasound-assisted extraction (UAE). However, they are often limited to the laboratory or pilot scale due to economic or technical bottlenecks. This article aims to explore recent advances and innovations related to the extraction of fatty acids from *Camellia*.

1. Introduction

Camellias are perennial trees belonging to the Theaceae family. This species is native and widely distributed in Asia (Pereira et al., 2022). In recent centuries, it was imported to Western countries due to the favorable conditions for its cultivation (The American Camellia Society, 2021). There are more than 200 species, including 22,000 varieties cataloged by the International Camellia Society (International Camellia Society, 2021). From an economic point of view, three stand out: *Camellia sinensis* (L.) Kuntze, *Camellia oleifera* Abel, and *Camellia japonica* (L.).

C. sinensis is a species of camellia used in tea cultivation. Widely consumed teas are made with it worldwide, including white, green, oolong and black tea (Namita et al., 2012). It is estimated that more than half of the world's population consumes one of these teas, with more than 3 billion cups consumed daily worldwide. Tea, with coffee and cocoa, are considered the three most popular non-alcoholic beverages worldwide (Chen & Chen, 2012). All commercial teas are obtained from the leaves of *C. sinensis*. Their differences lie in the different processing techniques to achieve different degrees of oxidation (Hicks, 2009). Currently, *C. sinensis* is cultivated in more than 52 countries worldwide. The latest available FAO reports estimated a global tea production of 5.07 million tons in 2013, observing a constant increase of around 6% yearly. It is estimated that in 2023 production will reach 4.17 million tons. Regarding its market price, the average in 2014 was USD 2.65 per kg (Food and Agriculture Organisation of United Nations, 2022; Food and Agriculture Organization of The United Nations (FAO), 2014). The rest of the parts of the plant are barely exploited at an industrial level, so the development of co-products could be an approach to increase economic benefits. In addition, by taking advantage of all the resources, the production system would meet the objectives of the circular economy. This could be achieved, for example, by using camellia seeds for fatty acid extraction.

C. japonica is the most relevant camellia at an ornamental level. Its

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use is almost limited to this purpose, so this specie is much less studied (Salinero & Corral, 2008). However, currently available studies indicate that this camellia species has a similar chemical composition to others; thus, different industrial applications could be developed (Pereira et al., 2022). In Spain, one of the largest producers in Europe, a production of 2.5 million camellia plants per year is estimated, exported as ornamental plants throughout the continent (Salinero et al., 2012). This crop generates a considerable volume of waste, including pruning, dry leaves, or the fall of flowers. There is no use for these products, as they are wasted raw materials. These materials could be studied to extract compounds such as lipids.

C. oleifera has been used traditionally for more than 1000 years for oil production (Fang et al., 2016), the camellia being the reference at present. The use of this species for oil production lies in its high lipid yield (40–60%) in China. The continued variety selection has made *C. oleifera* the most commonly available seed for the manufacture of camellia oil (Shi et al., 2020). According to the latest official data, in 2020, the harvesting area of *C. oleifera* in China reached 4.53 million hectares, the annual production amounted to 0.627 million tons, and the annual production value amounted to 18.36 thousand million dollars. This value is expected to continue to increase (Zhang et al., 2022). This lipid fraction is used as an edible oil, considered the principal edible oil in the kitchens of southern China today. In other regions of Asia, it only began to be used as an edible oil after its potential health benefits began to be recognized (Liang et al., 2017). These oils have also been traditionally used in cosmetics due to their protective effects on skin and hair (Yang et al., 2016).

The lipids present in the genus Camellias (mainly unsaturated fatty acids) have target bioactivities that could be exploited at an industrial level. This interest has increased exponentially in recent years. The manufacture of camellia lipids is the second most significant use in China, only behind tea, especially in the provinces of Jiangxi, Hunan and Zhejiang (southeast), where more than 50% of the population consumes this type of product daily (Salinero & Corral, 2008). The exploitation of these lipidic compounds could be developed with all the varieties analyzed since their chemical composition varies slightly from one variety to another (Liang et al., 2017). The part of the camellias most used to produce lipid-rich extracts are the seeds, regardless of the species studied. However, other less-used parts of the plant can also be used as a source of fatty acids. This is the case of pruning remains, which are currently a waste of resources that would be interesting to revalue (Kong et al., 2021). The extraction of lipids from these parts is characterized by lower yield and lower quality. Therefore, developing and optimizing new extraction methods is necessary to increase the process yield. The resulting extracts would have considerable value in the market since the fatty acids present in camellias have different biological properties (including antiaging, antimicrobial, or anti-inflammatory) (Djilani & Dicko, 2012). These properties are due to the high level of unsaturation of the fatty acids present in camellias (Garcia-Jares et al., 2017). However, despite the significant progress made in the last century, camellias use at an industrial level still faces several challenges. The key to success in growing camellias for lipid production in different regions of the world is to identify promising clones with high yield and lipid quality for specific habitats. This process will require many selections and tests. Those varieties selected for similar climates in China and other Asian countries could be the starting point. However, the cost of labor is much higher in Western countries than in China, so a centralized operating system with a high level and efficiency of mechanization may be essential for the industry to be profitable in these countries (Liang et al., 2017).

This review focuses on the phytochemistry of *Camellia* spp., combining the description of its most prevalent fatty acids with their extraction techniques to provide a current perspective on its potential to be exploited for nutraceutical purposes.

2. Chemical characterization of the genus Camellia

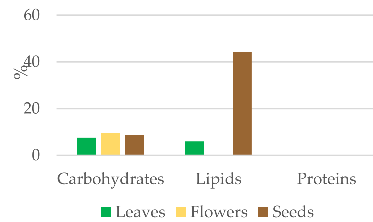
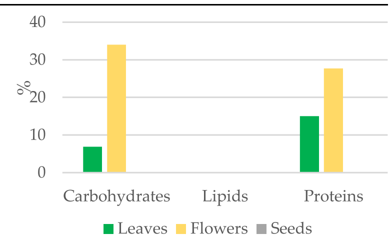
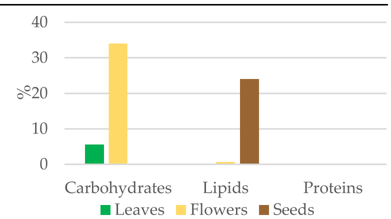
Plants have been consumed since immemorial times due to their nutritional value and acceptability (Pereira, Jimenez-Lopez, et al., 2020). Nowadays, some plants can be considered undervalued and/or underused species although they could be used to improve the human diet and rise food production levels (Baldermann et al., 2016), promoting the economic development of flower and plant-producing regions (Rivas-García et al., 2021). This is the case of *Camellia* sp. (family Theaceae). The most common species are *C. sinensis* (tea production), *C. oleifera* (oil production), and *C. japonica* (ornamental flowers) (Pereira et al., 2022). However, the great diversity of species and varieties of camellias implies that the study of its chemical composition is complex (Meng et al., 2019). The nutritional composition of these species varies significantly depending on the part of the plant analyzed and the species. This means that depending on the plant part, the use and processing of the raw material can be very different (Pereira et al., 2022). In all cases, the concentration of the different compounds is the result of secondary metabolism, involved in the adaptative and defensive responses of plants against environmental conditions and threats (García-Pérez et al., 2021), influenced by a set of both edaphoclimatic and physical factors (*i. e.*, geographical area, climate, soil properties, stresses factors as drought, heavy rains, or overexposure to ultraviolet light) (Abe et al., 2021). For example, concerning water content, it is one of the main components in the flowers of *C. japonica* (>87%, fresh weight) (Chen et al., 2020; Fernandes et al., 2020; Shi et al., 2019), while in the leaves of *C. sinensis,* it can decrease up to 58% fw (Dong et al., 2022). Therefore, the drying process is an essential step for the quality and value of camellia products (Chen et al., 2020; Fernandes et al., 2020; Shi et al., 2019). Especially in camellia seeds, moisture ensures high germination (Song et al., 2017).

Camellias also have a significant content of protein, fat, total dietary fiber, and minerals. *C. sinensis* flowers had 34.02% dw carbohydrates, mainly glucose, fructose, sucrose, and polysaccharides (Chen et al., 2020) (Table 1). The content is much lower in the leaves and branches of this species, with a carbohydrate content of 6.9% dw (Wang et al., 2010). *C. japonica* flowers have a similar carbohydrate content to *C. sinensis* flowers (Chen et al., 2020) and leaves (4–7% dw), where the main sugars are glucose, xylose, mannose, and galactose (Sanz et al., 2020; Shevchuk et al., 2020). *C. oleifera* seed meal has a 40% dw of carbohydrates (Ni et al., 2021), content much higher than the rest of the parts of this specie of camellia: 7.57% in the leaves (Feng et al., 2022), 9.32% in the flowers (Feng et al., 2022) and 8.69% in the whole seeds (Feng et al., 2022).

Protein is the macronutrient with the most constant composition between different plant parts. For example, protein content in *C. sinensis* flowers is estimated at 27.72% dw (Chen et al., 2020), while in leaves is 10–20% dw (Shevchuk et al., 2020). However, the flower protein content varies significantly according to the maturation state (decreases with the development of flowers) (Joshi et al., 2011). The callose plugs from the *C. japonica* pollen tube have similar concentrations with a protein concentration of 24% of dw (Nakamura et al., 1984). Among the determined amino acids are aspartic acid, serine, histidine, arginine, γ-aminobutyric acid, threonine, tyrosine, valine, methionine, isoleucine, phenylalanine, lysine, and theanine (Chen et al., 2020).

The fatty acid content of the *C. oleifera* seed oil was 35.03–53.47% dw, with significant oleic acid content (80%), indicating a highly stable and nutritious oil. The oil was also rich in carotenoids, polyphenols, flavonoids, β-sitosterol, and squalene (Long et al., 2022). The other species of camellias have a lower lipid composition. For example, *C. japonica* seeds' lipid content ranged between 16.1% and 31.9% (Barreiro et al., 2021), *C. sasanqua* 10.5%, *C. reticulata* 2.1%, and *C. hibrida* 2.1% (Bailón et al., 2014). However, some studies reflect that some varieties of *C. japonica* can be used as an oilseed crop after selecting genotypes with high lipid and oleic acid content (Bailón et al., 2014). The content is much lower in other parts of the plant, quantifying only 3–9% dw in the leaves of *C. oleifera* (Shevchuk et al., 2020) and

Table 1
Composition according to species and part analyzed.

	Carbohydrates	Lipids	Proteins	
C. oleifera				
Flowers	9.32	–	–	
Seeds	8.69	35.03–53.47	–	
Leaves	7.57	3–9	–	
Ref.	(Feng et al., 2022)	(Long et al., 2022; Shevchuk et al., 2020)		
C. sinensis				
Flowers	34.02	–	27.72	
Seeds	–	–		
Leaves	6.9	–	10–20	
Ref.	(Chen et al., 2020; Wang et al., 2010)		(Chen et al., 2020; Shevchuk et al., 2020)	
C. japonica				
Flowers	34.02	0.51–0.82	–	
1 Seeds	–	16.1–31.9	–	
Leaves	4–7	–	–	
Ref.	(Chen et al., 2020; Sanz et al., 2020; Shevchuk et al., 2020)	(Barreiro et al., 2021; Kim et al., 2005)		

0.51–0.82 g/100 g dw in the flowers of *C. japonica* (Kim et al., 2005). Similar contents were reported by other authors (0.31 g/100 g dw) (Fernandes et al., 2020). However, lipid composition can be increased by regulating ultraviolet radiation and nitrogen levels as camellia plants survive UV radiation by decomposing triglycerides and accumulating phospholipids and galactolipids to avoid damaging cells (Du et al., 2022).

Furthermore, a series of compounds in lower concentrations can be found. These compounds are characterized by secondary metabolites of the plant and are represented by phenolic compounds, terpenoids, and pigments (Pereira et al., 2022). The concentration of these compounds will determine the possible applications of the raw material. Therefore, it is essential to know the major compounds in each part of the plant (Table 2).

3. Evaluation of different extraction techniques

Regardless of the application of lipid fraction of camellia (edible oil or cosmetic), it is first necessary to carry out an extraction to obtain a sample rich in lipids. There are several extraction methodologies for obtaining lipids from camellias. Routine extraction methods include presses (hydraulic or expeller) and the use of organic solvents (Garcia-Jares et al., 2017). These techniques are characterized by having a big environmental impact. For this reason, new extraction techniques are developed, such as supercritical fluid extraction (SFE) or ultrasound-assisted extraction (UAE). The main advantages and disadvantages of each technique can be seen in Table 3. All these emergent techniques must comply with six principles: *(1)* innovation by the selection of varieties and use of renewable plant resources; *(2)* use of alternative solvents and principally water or agro-solvents; *(3)* reduce energy consumption by energy recovery and using innovative technologies; *(4)* production of co-products instead of waste to include the bio-and agro-refining industry; *(5)* reduce unit operations and favor safe, robust and controlled processes; and *(6)* aim for a non-denatured and biodegradable extract without contaminants (Chemat et al., 2012). In many cases, to satisfy all these principles, several extraction techniques are combined. This combination increases the yield of the operation (Fang et al., 2016).

3.1. Mechanical press extraction

Mechanical press extraction is one of the traditional extraction methods for camellia oil (Li & Liu, 2011). There are several pieces of equipment to carry out the process. In China, the largest camellia oil-producing country, hydrolytic presses have been used to extract camellia oil since the 1960s. However, hydraulic presses are still used in the camellia seed producing areas due to the small production scale and less cost (Robardset al., 2009). To carry out this process, it is necessary to crush the raw material (mainly seeds). Afterwards, the grinding is subjected to pressure, which makes the cells release their oils (Li & Liu, 2011). During this process, temperatures are kept high (40 °C) to maintain the oil in a fluid state. For this reason, in large-scale-plants, the traditional press was changed to the screw press (type 95 and type 200) in the '80s (Robards et al., 2009). This technique is suitable for extraction from seeds with high oil contents (>25%) (Savoire et al., 2013). Cold press extraction optimization studies concluded that the moisture content, the applied pressure, and the extraction time significantly affect the extraction yield. Pressure, temperature, and time affected energy consumption (Huang et al., 2019). Examples of extractions carried out with this method are shown in Table 4. The extraction yield of the different processes varies since, in some cases, a stage before pressing, which consists of peeling the seeds, is developed. This process also seeks to obtain a lipid extract with better organoleptic qualities and with a lower wax content. In addition, the peeling ensures that the temperature

Table 2
Composition according to part analyzed.

Part	Main components	Concentration of fatty acids	Applications
 **Flowers**	Phenolic compounds, pigments, carbohydrates, protein, vitamins, amino acids, flavonoids, terpenoids, and fatty acids.	0.31 g/100 g fw.	Ornamental and cosmetics.
[Ref.]	(Pereira et al., 2022; Xin-lei et al., 2022)	(Fernandes et al., 2020)	(Pereira et al., 2022)
 **Seeds**	Unsaturated fatty acids, peptides, minerals, and vitamins.	Fatty acids: oleic acid, linoleic acid, and linolenic acid. Higher concentrations of fatty acids in *C. oleifera* seeds (up to 80%), then *C. japonica* (46.23%), *C. sasanqua* (10.5%), *C. reticulata* (2.1%) and *C. hibrida* (2.1%).	High-quality edible oil, medicines, healthy foods, and daily chemical products.
[Ref.]	(Yu et al., 2022)	(Bailón et al., 2014; Yu et al., 2022)	(Quan et al., 2022)
 **Leaves**	Phenolic compounds (catechins), minerals, and vitamins.	Fatty acids: lauric, myristic, palmitic, oleic, linoleic, and linolenic (5–40 mg/g)	Tea production; cosmetics.
[Ref.]	(Wang et al., 2022)	(Bhuyan & Mahanta, 1989; Guo et al., 2020)	(Koch et al., 2019)
 **Pruning**	Carbohydrates (up to 60%), phenolic compounds, protein, and minerals.	No reliable concentrations but pruning increase significatively fatty acids leaves content.	Agriculture.
[Ref.]	(Sanz et al., 2020)	(Chen et al., 2021; Ye et al., 2021)	(Borgohain et al., 2020)

does not rise so much during the extraction (Li & Liu, 2011). However, one of the main problems of this technique is low yields (Huang et al., 2019; Li et al., 2014). These low yields are due to some lipids left in the pressed cakes. To increase the rate of lipid recovery, mechanical press extraction is usually combined with solvent extraction, which can recover the residual lipids from pressed cakes in the industry (Li et al., 2014).

3.2. Solvent extraction

The use of organic solvents in extraction is one of the most routine and historically used techniques owing to its high yield and continuous production (Mandal et al., 2015). However, it is not the best option to extract lipids from camellias. In many cases, the production of lipids is relatively scarce, and many solvents do not lead to a final product that meets the quality requirements (Fei, 2011; Yu et al., 2013). Solvent extraction is usually applied to remove the lipids from the cakes after mechanical press extraction (Li et al., 2014; Yu et al., 2013). The efficiency of this extraction will depend on the lipid content of the cake, the solvent used, and the temperature; petroleum mixtures are commonly used in the Chinese industry (Robards et al., 2009). A higher overall yield is obtained, reaching a total lipid fraction yield of over 95% (Li et al., 2014; Yu et al., 2013).

Currently, the most widely used solvent is hexane (Lavenburg et al., 2021), and its replacement with greener solvents such as ethanol (Lavenburg et al., 2021), butyl-acetate, n-butyl alcohol, and sodium carbonate has been proposed (Wu et al., 2018; Yu et al., 2013). However, these solvents have several drawbacks, such as high cost and high waste production. For example, the extraction yield of butyl acetate exceeded 96% under optimal conditions, but its residue content was 11%, which is higher than that of hexane (Li et al., 2022). In addition to residual solvents, benzo(a)pyrene is another problematic substance produced during solvent extraction due to high-temperature roasting and milling without shelling (Wu et al., 2012). Other examples of extractions done with solvents can be seen in Table 4.

3.3. Enzymatic methods

The most used part for the extraction of camellia lipids is the seeds. Seeds are characterized by having a cell wall composed of cellulose, hemicellulose, pectin, and lignin that prevents the release of all kinds of compounds, reducing the yield of the extractions (Zhang et al., 2012). The use of enzymes for the extraction of lipids in camellia has promising results (Table 4) due to the ability of the enzymes (*e.g.*, cellulase, protease, amylase, and pectinase) to break down the compounds that make up the cell wall (Solís et al., 2016). However, combining enzymes does not always lead to a higher yield because enzymes frequently have different optimal pH values and temperatures, which can impede their synergistic effect (Zhao, Diaby, et al., 2022). Table 4 shows the optimization studies of enzyme extraction of camellia oils in the literature. However, it must be considered that for this technique to be viable, the high cost of the enzymes used must be assessed. This disadvantage can be compensated by recycling enzymes by enzyme immobilization. For example, immobilized alcalase and cellulase can be reused for more than ten cycles to extract *C. sinensis* lipid fraction (Li et al., 2022).

3.4. Supercritical fluid extraction (SFE)

Supercritical fluid extraction (SFE) extracts total fat (Ivanov et al., 2011). This method pushes fluid to a temperature and pressure above the critical point so that the fluid behaves simultaneously as a liquid and a gas. This double behavior increases extraction due to faster and more complete penetration into solid matrices because of the lower viscosity of the extractant. The most widely used solvent is CO_2 for its thermodynamics, heat transfer properties, non-toxic nature, and low cost. In addition, it has a low critical point (31 °C, 73 bar) (Ahangari et al., 2021; Pereira, Jimenez-Lopez, et al., 2020). The resulting extracts are of high quality because of the absence of solvent residue and the low temperature applied (Li et al., 2022). According to the data in the bibliography (Table 4), the mean pressure, for the extraction of camellia lipids, ranges between 30 and 40 MPa. The typical range of extraction temperatures is 40–70 °C. All this evidence indicates that this extraction technique is a promising alternative to obtaining camellia lipids. However, this technique requires high maintenance costs and high capital, so the most viable market for camellia lipids obtained by SFE is the high-end market due to the high quality of the lipid extracts obtained and the high cost (Li et al., 2022).

3.5. Microwave-assisted extraction (MAE)

Microwave-assisted extraction (MAE) is a relatively new technique that combines microwave and traditional solvent extraction (Delazar et al., 2012). The extraction process uses microwave energy to exert pressure on cell walls and create micropores through which compounds are released (Sparr Eskilsson & Björklund, 2000). This has led to the development of several advanced MAE instrumentation, and methodologies like pressurized MAE and solvent-free MAE (Delazar et al., 2012). However, up to date, most of the studies of MAE for camellia lipid

Table 3
Main advantages and disadvantages of the extraction techniques to obtain lipids from Camellia.

Technique	Advantages	Ref.	Disadvantages	Ref.
CP	✓Not corruption of lipids with chemicals and temperature.	Zhu et al. (2020)	× Refining step. ✓ × Elevate energy consumption	Li and Liu (2011) Huang et al. (2019)
SE	✓Routinely used.	Anna and Wypych (2014)	✓Risk of flammability and contamination.	Silva et al. (1998)
	✓Low cost of equipment.		✓Solvents toxicity.	Anna and Wypych (2014)
	✓Only solvents recognized as GRAS and food grade solvents can be used.		✓Large volume of solvents.	Pereira, Jimenez-Lopez, et al. (2020)
EAE	✓Low volume solvents, low energy cost and expenses, elimination of intermediate stages (*e.g.*, degumming).	Fang et al. (2016)	✓Cost of enzymes involved, recovery and reuse of enzymes.	Das et al. (2021)
SFE	✓Reduction of solvents, operating time.	Ivanov et al. (2011)	× Limitation to extract polar lipids (it can be reduced by using co-solvents).	Ivanov et al. (2011)
	✓Greater safety and cleanliness		× Volatile polar modifier	Kim et al. (2012)
MAE	✓Reduction of solvents, operating time, higher extraction rate, and lower cost ✓Oxidation avoided.	Delazar et al. (2012) (Echave et al., 2020)×	× Thermal stress and localized high pressures can decrease recovery of volatile oils.	Echave et al. (2020)
UAE	✓ High ease of coupling other techniques. Reduction of solvents, operating time, cost	Vilkhu et al. (2008)	×Temperature rise, lack of uniformity in the distribution of ultrasound energy.	Carreira-Casais, Carpena, et al. (2021)
MSPD	✓ Repeated centrifugation and/or filtration steps and re-extraction procedures are not necessary. Also, the solvent removal process is not necessary. Reduction of solvents, and handling time required for sample preparation.	Tu and Chen (2018)	× Low reproducibility, sorbent bed clogging.	Rawa-Adkonis et al. (2006)

Abbreviations: CP: cold press; SE: solvent extraction; EAE: enzyme assisted extraction; SFE: Supercritical fluid extraction; MAE: Microwave assisted extraction; UAE: ultrasounds assisted extraction; MSPD: matrix solid phase dispersion; GRAS: generally recognized as safe.

recovery have been done at a laboratory scale (Table 4) so the cost-effectiveness at the industrial scale remains to be evaluated. Only one study at the pilot plant level (Ye, Zhou, et al., 2021), in which MAE is used as a pretreatment for camelia oil extraction, achieved a high oil yield (nearly 90%). This coupling of techniques, considering the microwaves a pretreatment to carry out another subsequent extraction, will also allow the elimination of unwanted compounds. For example, *C. oleifera* seeds, after a short microwave treatment (30 s) have an 83% yield. After a second microwave treatment, saponins are eliminated. In addition, when a subsequent stage of enzymatic extraction is carried out, it is possible to obtain 95% yields, values comparable to lipid extraction, using solvents such as hexane in other vegetable matrices (Zhang et al., 2012).

3.6. Ultrasounds-assisted extraction (UAE)

Ultrasounds-assisted extraction (UAE) is a technique that is gaining attention for the extraction of high-value compounds such as vegetable oils (Esclapez et al., 2011). UAE employs the cavitation effect of high-intensity ultrasonic sound waves to disrupt the cell walls of oil seeds, accelerating the penetration of solvent and enhancing the dissolution and transfer of target compounds (Carreira-Casais, Carpena, et al., 2021). This technique can be used in oil extraction. The most determining parameters in the process will be power, frequency, temperature, time, and solvent. Generally, an increase in temperature leads to a reduction in the surface tension and the vapor pressure of the solvent, which leads to an increase in the diffusion of the solvent in the cell, and therefore the extraction efficiency increases. However, at temperatures close to the boiling point of the solvent, the vapor pressure increases, which leads to a decrease in the efficiency of the process since the pressure differences between the inside and outside of the bubbles are smaller and, therefore, collapse less intensely (Marhamati et al., 2020).

To date, the use of UAE to extract lipids from camellias has been explored mainly at the laboratory scale (Table 4). According to these studies, low frequencies (<40 kHz) improve the extraction yield. Furthermore, it was observed that *C. oleifera* seed oil yield increased with increasing ultrasonic power (until ≈40 kHz) (Anvar, 2009). The effects of ultrasound treatment on oil quality, especially lipid oxidation, should be further evaluated. The economic feasibility, especially energy consumption, requires further investigation (Li et al., 2022).

From an economic point of view, the profitability of camellia fatty acid extraction methods can vary depending on several factors, such as the cost of equipment, reagents, and energy resources used (Barreiro et al., 2021). Traditional extraction methods, such as solvent extraction, are widely used and generally less expensive in terms of initial investment. However, these methods may require large amounts of organic solvents and a long extraction time, which could increase operating costs and environmental risks associated with the disposal of used solvents (Pereira, Jimenez-Lopez, et al., 2020). On the other hand, emerging techniques such as UAE and MAE have gained interest in recent years due to their ability to speed up the extraction process and reduce solvent consumption. These techniques can provide more efficient and faster extraction, leading to higher profitability in the long run (Carreira-Casais, Carpena, et al., 2021). However, it is essential to note that the economic profitability of these emerging techniques may vary depending on the scale of production and local energy costs (Jiménez-Moreno et al., 2020). In addition, the availability of specialized equipment and the need for additional training to use these techniques can influence their profitability (Laranjeira et al., 2022). Therefore, economic studies must be conducted specifically for each production system due to the considerable variability of situations that can arise. Furthermore, to enhance financial performance, it would exploit the by-products of camellia for the extraction of other bioactive compounds, as observed in previous studies (Pereira et al., 2022).

4. Fatty acids profile of the genus Camellia

The composition of the extract obtained and its properties will be determined by the extraction method used (Garcia-Jares et al., 2017). Therefore, to improve the method's efficiency, it is necessary to evaluate the nature of the raw material and the method parameters and their interaction (Pereira, Jimenez-Lopez, et al., 2020). Other parameters that affect the yield of the process include the state and quality of the raw material, including the degree of maturity and the storage conditions or the possible damages caused by the transport (Li & Liu, 2011).

Regarding their lipid profile, each variety of camellias has a slightly

Table 4
Extraction techniques to obtain lipids from different parts of Camellia.

Plant/ part	Part	Conditions	Yield	Comments	Refs.
Mechanical press extraction					
C. oleifera	Seeds	71 °C, 36.86 MPa, 23.97 min	39.32%	Optimization test.	Huang et al. (2019)
		Low temperature.	90.8%	Similar quality parameters than solvent extraction oil.	Yang et al. (2019)
	Seeds, cake	RT, 24 h	47.1 μg/kg benzopyrene	Processes of bleaching and winterization could reduce benzopyrene content to a safety range.	Wu et al. (2012)
Solvent extraction					
C. oleifera	Seeds	EtOH (100%), S/L 1:12, 90 °C.	45.36%	77.57% (w/w) of the lipids were 10-octadecenoic; UFAs 88.01% (w/w) of the total fatty acids.	(Liu, Liang, et al., 2019)
		Petroleum ether	42.8–46.1%	67.7–76.7% oleic acid, 82–84% UFAs, 68–77% MUFAs, and 7–14% PUFAs.	Ma et al. (2011)
		Sodium carbonate (1.48 M), S/L 3.85, 3.23 h, RT	88.8%	Higher moisture content and lower free acidity content than oils obtained with other techniques.	Yu et al. (2013)
		Hexane, 8 h, Soxhlet extractor	100%	No significant differences in the amounts of the major fatty acids using different extraction methods.	(Fang et al., 2015)
		Urea	95.0–99.3% of oleic acid	Pre-step of saponification followed by an acidification.	(CN101845362B, 2010)
Enzyme assisted extraction					
C. oleifera	Seeds	Protease or cellulase	70%	Optimal extraction conditions: acid protease 0.1% (w/w), 3 h, 55 °C, S/L 1:10.	(Fang et al., 2010)
		Combination of protease/cellulase	82.37%	Yield can be increased with demulsification stage with ethanol (yield of 91.38%).	Fang et al. (2016).
		Protease	75%	Optimal conditions: pH 6.8, 45 °C, 18 h.	Qian et al. (2021)
		Combination cellulase/alcalase	93.5%	0.80% cellulase (v/w), pH 6.0, 50 °C, 1 h. Then, 0.70% alcalase, pH 9.2, 57 °C, 4.1 h.	Meng et al. (2018)
C. sinensis	Seeds	Cellulase	94.14%	8000 U per g of tea seed powder, pH 9.0, 1h, 50 °C.	Peng et al. (2019)
Supercritical fluid extraction					
C. sinensis	Seeds	45 °C, 32 MPa, 89.7 min.	29.2%	Higher yields than with Soxhlet (25.3%). Approximately 80% of the extracts were UFAs.	Wang et al. (2011)
		70 °C, 40 MPa, 20 min	54%	Extraction yielded half of Soxhlet. Efficiencies increased by adding 15% ethanol.	Rajaei et al. (2005)
	Flowers	50 °C, 30 MPa, static time of 10 min and a dynamic time of 90 min	1.2%	59 compounds characterized: alkanes 45.4%, esters 10.5%, ketones 7.1%, aldehydes 3.7%, terpenes 3.7%, acids 2.1%, alcohols 1.6%, ethers 1.3%, others 10.3%.	Chen et al. (2014)
C. oleifera	Seeds	45 °C, 36.4–40 MPa	23%	20 different compounds identified.	Zhou et al. (2012)
		40 °C, 40 MPa	40.94%	Combination of supercritical fluid extraction and molecular distillation lower yield by 78.50%.	Zhou et al. (2019)
C. japonica	Seeds	60 °C, 35 MPa	72.6%	Soxhlet yield 36.8%.	Jeon et al. (2012)
Microwave-assisted extraction					
C. oleifera	Seeds	60 °C, 300 W, n-hexane (solvent: solid 7:1), 12 min	85.2%	With two extractions yields of 98.3%.	Xiao et al. (2012)
		50 °C, 10 KW, dW (1:7 w/v), 30 s	95%	Nearly twice the yield than using solvents alone.	(Zhang et al., 2012)
		70 °C, 800 W, W (S/S 4:1), 3 h	91.85%	High time and temperature would facilitate oil release at first. Then, increase emulsion formation.	Zhang et al. (2012)
		320 W, EtOH 95% (S/S 10:1), 10 min	57%	Extraction of residual oil in defatted cake of camellia.	Tang et al. (2014)
		640 W, 8 min	75.35%	Pilot scale.	Ye, Zhou, et al. (2021)
C. sinensis	Seeds	70 °C, 440 W, 38 min	26.75%	Yields increase in combination with UAE.	Hu et al. (2019)
Ultrasound-assisted extraction					
C. oleifera	Seeds	55 °C, 155 W, 31 min, L/S ratio 5 mL/g	44.55%	84.47% UFAs, more than 76.15% oleic acid	Wu and Li (2011)
		30 °C, 50 W, 24 kHz, 40 min, S/L 6:1 (n-hexane)	85.21%	Yield increase with ultrasonic power and decrease with temperature	Anvar (2009)
Combined techniques					
C. sinensis	Seeds	Microwave power 440 W, ultrasonic power 550 W, 38 min, L/S 8 mL/g, 70 °C	31.52%	Fatty acid composition like those obtained by Soxhlet extraction, but with better physicochemical properties and a higher content of bioactive components	Hu et al. (2019)

Abbreviations: RT: room temperature (22 °C); S/L: solid to liquid ratio; S/S: solid to solid ratio; L/S: liquid to solid ratio; W: water; EtOH: ethanol; dW: distilled water; SFAs: saturated fatty acids; MUFAs: monounsaturated fatty acids; PUFAs: polyunsaturated fatty acids.

different composition (Liang et al., 2017). All camellias are a potential source of unsaturated fatty acids (UFAs) (Fig. 1), mainly oleic acid and linoleic acid (Feás et al., 2013). Average values are around 82–84% UFAs (67.7–76.7% oleic acid), 68–77% monounsaturated fatty acids (MUFAs), and 7–14% polyunsaturated acids (PUFAs) (Ma et al., 2011). These percentages are much higher than common oils for food use, as reflected in Fig. 1. Based on these data, camellia oil is characterized by the presence of fatty acids that are desirable in human and animal diets and are present in ratios similar to those of most used edible oils (e.g., olive oil), but with a lower content of PUFAs. However, other oils for human consumption have reported a greater variety of fatty acids, with extra virgin olive oil being particularly notable (i.e., myristic acid, heptadecanoic acid or docosanoic acid) (Jimenez-Lopez et al., 2020), which makes their comparation difficult. In addition, for the comparison of the different types of oils, different edaphoclimatic factors should also be taken into account, since the lipid profile will always depend on a complex interaction between several environmental factors associated with the area of cultivation, tree age, and harvest time (Chami et al., 2023). In addition, the UFAs content of camellias can reach 90%, which makes it the edible oil with the highest UFAs content (Feás et al., 2013). The high concentration of oleic acid makes this oil comparable to olive oil (Fang et al., 2016). *C. sinensis* has proven to be the variety with the

Table 5
Fatty acid profiles (% w/w) of different common oils.

Fatty acid	*Camellia*		*Other edible oils*									
	Cold-pressed	Refined	Virgin olive oil*	Sunflower	Palm	Sesame	Avocado	Soybean	Pumpkin	Rapeseed	Coconut	Peanut
Palmitic	9.3	7.9	16.5	6.7	44.0	9.6	14.1	9.4	11.6	4.7	7.5–10.5	7.5
Palmitoleic	0.2	0.1	1.8	0.1	Nd	0.2	5.7	0.1	0.1	0.1	Nd	0.1
Stearic	1.9	1.8	2.3	2.4	4.5	5.9	0.4	5.6	6.6	1.6	1.0–3.2	2.1
Oleic	79.1	82.0	66.4	11.5	39.2	40.8	69.1	41.8	32.7	58.8	5.0–8.2	71.1
Linoleic	8.4	6.8	16.4	79.0	10.1	41.0	9.6	41.3	46.4	20.2	1.0–2.6	18.2
Linolenic	0.3	0.4	1.6	0.2	0.4	0.3	0.6	0.7	0.2	8.8	Nd	Nd
Arachidic	<0.1	<0.1	0.4	Nd	0.1	0.6	0.1	0.6	0.5	0.6	0.2–1.5	1.0
Eicosaenoic	0.4	0.6	0.3	Nd	Nd	0.2	0.2	0.2	0.1	1.2	Nd	Nd
Behenic	<0.1	<0.1	0.2	Nd	Nd	0.1	<0.1	0.1	0.1	0.3	Nd	Nd
Total SFAs	11.3	9.9	19.4	9.3	49.9	15.6	14.7	15.7	18.7	2.5	8.7–15.2	10.7
Total MUFAs	79.7	82.6	68.2	11.6	39.2	41.2	75.0	42.1	32.9	60.1	5.2–8.2	71.1
Total PUFAs	8.7	7.2	18.0	79.1	10.5	41.3	10.2	46.6	48.4	29.0	1. – 2.6	18.2
Ref.	[a]	[a]	[b]	[b]	[c]	[a]	[a]	[e]	[a]	[b]	[b,d]	[b]

Abbreviations: SFAs: saturated fatty acids; MUFAs: monounsaturated fatty acids; PUFAs: polyunsaturated fatty acids. Nd: not determined. **Ref.**: [a]: (Robards et al., 2009); [b]: (Orsavova et al., 2015); [c]: (Mancini et al., 2015); [d]: (Lal et al., 2003); [e]: (Frančáková et al., 2015). *Type of olive oil according to International Olive Oil Council Regulation (2022).

lowest proportion of oleic acid (≈60%) but with the highest proportion of linoleic and stearic acid (Garcia-Jares et al., 2017). Other UFAs present in *Camellia* spp. include linolenic acid, and palmitoleic acid (Yu et al., 2022).

Based on these data, camellia lipid extracts meet international nutritional standards for "omega foods" (Su et al., 2014). Camellias are rich in linoleic acid (4.85–10.79%), an essential omega-6 fatty acid, and an omega-6:omega-3 ratio, which is considered healthy (Cheng et al., 2018; Yang et al., 2016; Zhou et al., 2017). The health effects of UFAs are supported by many studies that have shown that they have anti-inflammatory effects, regulate blood lipids, delay atherosclerosis, and effectively prevent hypertension, hyperlipidemia, and other cardiovascular diseases (Xiao et al., 2017). In addition, these omega-6 and -3 fatty acids are essential since the human body cannot produce them, so they must be ingested into the diet (1–2% of dietary energy) (Innis, 2007). Therefore, the lipid fraction obtained from camellias has commercial value (Kostik et al., 2013). Moreover, this oil is beneficial in terms of consumers' health and complies with the principles of sustainable development of food production (Sagan et al., 2019). All these characteristics make this product known as "Eastern Olive Oil" due to its similarity to olive oil (Yang et al., 2016). The main differences between olive oil and camellia lipid extracts are the content of arachidonic acid and myristic acid, present only in camellia and highly important in the human diet due, for example, to their presence in the brain (Salinero & Corral, 2008). The rest of the fatty acids analyzed were present in both oils, albeit in different concentrations, which makes camellia lipid fraction an appealing product from a health point of view (Salinero & Corral, 2008).

Compared to other edible oils (*e.g.*, sunflower or olive) (Table 5), the amount of saturated fatty acids (SFAs) present in camellia is lower (Giuffrè et al., 2017; Salinero & Corral, 2008). This is beneficial since consuming this type of fat is associated with increased cholesterol levels and the likelihood of coronary heart disease (German & Dillard, 2004). The main SFAs of the camellia genus are myristic acid, arachidic acid, palmitic acid, and stearic acid (Yu et al., 2022). Despite being less abundant than UFAs, it is possible to quantify relevant levels of palmitic acid (8.37–8.92%) and stearic acid (1.96–2.64%) (Shi et al., 2020).

However, these values can vary considerably from one study to another. This is because the concentration of each one of the compounds is strongly linked to the edaphoclimatic and physical conditions of the crop, including geographical region, climate, type of soil, harvesting season or stress episodes (droughts, severe radiation, intense rains) (Abe et al., 2021; Venthodika et al., 2021). Comparing different types of oils can be challenging due to the significant variations observed within the same oil type produced in different regions. For instance, notable differences have been observed between olive oil produced in Italy and Algeria, where the quality of Algerian olive oil was inferior. However, it should be noted that improvements in cultivation and processing techniques could enhance the quality of Algerian olive oil (Louadj & Giuffrè, 2010). This highlights the need for a comprehensive understanding of the factors influencing oil production. Consequently, it is reasonable to assume that Camellia oil production may exhibit similar behavior. Furthermore, the content of these bioactive substances in the extracts is highly dependent on the extraction and processing technology. For this reason, the extraction of camellia lipid fraction more efficiently and with a higher yield has obtained a growing interest in recent years.

5. Applications

5.1. Lipid extracts

The chemical composition of camellia oils makes them suitable for edible and non-edible uses. However, the use of these oils in food continues to be practically exclusive to Asia despite their high resistance to temperature and high smoke point that ensures that the oil maintains its quality even when subjected to high heat treatments (Allen, 2015). Moreover, this oil is characterized by not providing aroma and flavor to dishes, so undernotes and aftertastes of oil are avoided. All these properties mean that in Asia, it is chosen as a reference oil to carry out tempuras (Robards et al., 2009). Prestigious chefs around the world have included camellia oils in their recipes. These uses are backed by quality certificates such as the China Organic Food Development Center, the United States Department of Agriculture (USDA) certificate from the United States Ministry of Agriculture, and the sanitary certificate from the Australian National Heart Tick Foundation (Salinero & Corral, 2008). Therefore, camellia oil can be an alternative and exotic oil to accompany dishes, with beneficial effects on health (Salinero & Corral, 2008).

Other uses of camellia lipids include cosmetics such as shampoos, lotions, hair conditioners, soaps, creams, and lipsticks. Their main properties include restoring elasticity, balance, and smoothness of the skin, anti-aging, antioxidant (Lee & Yen, 2006), anti-asthmatic (Lee et al., 2019), and antimicrobial (Kong et al., 2021; Ramachandran et al., 2020). These properties are due to the bioactive compounds like essential fatty acids, phenolic compounds, lignans, or sesamin (Lee & Yen, 2006). These properties are remarkable for the cosmeceuticals industry; hence several patents have been developed in recent decades. For example, The Boots Company PLC developed a skin care product containing extracts of *C. sinensis* to combat skin damage caused by free radicals (Pykett et al., 2007). Other examples include the patents developed by Estée Lauder, Dermacell Cosmetics, or Plante System, which have used camellias as a by-product to make creams, shampoos,

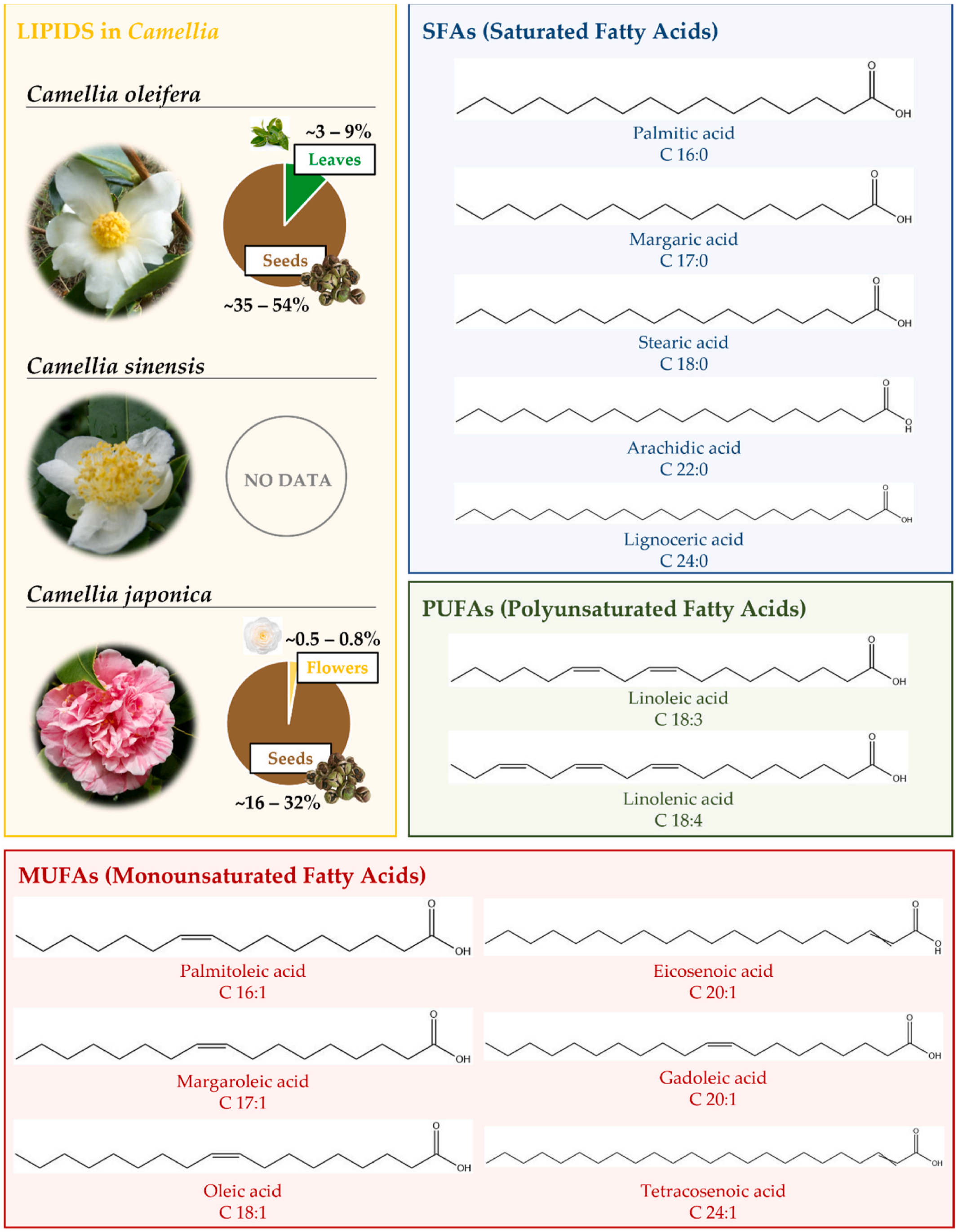


Fig. 1. Main fatty acids present in Camellia.

and nail polish removers (Salinero & Corral, 2008).

Camellia's lipids can also be used in cosmetics due to the functional properties of lipids, which include acting as a barrier to prevent the body from encountering pollutants, allergens, or infections (Wang et al., 2004) and to pass desired compounds (*e.g.*, vitamins, phenolic compounds) (Chen et al., 2016). To use camellia lipid fraction with one or another function, it is necessary to characterize the lipid profile since free fatty acids and terpenes are skin penetration enhancers (Chen et al., 2016). Therefore, although camellia lipids improve penetration, more research is needed to objectively assess its superiority over other penetration enhancers currently used in the cosmetic industry (Robards et al., 2009).

In recent years, efforts have been made to investigate its use in functional food formulations or even in medicines due to its beneficial properties for health. These properties include regulating lipid and blood pressure levels, inhibiting tumor growth, protecting against Alzheimer's disease, and anti-asthmatic, anti-diabetic, anti-inflammatory, antioxidant, and antibacterial properties (Li et al., 2022). For example, a study made with the lipid fraction of different seeds showed that *C. oleifera* and blended lipid fractions were more efficient than soybean oil in elevating serum high-density lipoprotein (HDL) cholesterol and decreasing the ratio of low-density lipoprotein (LDL) to HDL cholesterol in hamsters (Chou et al., 2018). Fatty acids from *C. oleifera* can also dramatically attenuate fat deposits, serum levels of total cholesterol, total triglycerides, LDL-cholesterol, fasting plasma glucose, atherosclerosis index, hepatic steatosis, and inflammation in high-fat diet-induced obese mice (Huang et al., 2021). However, using camellia lipids as a potential clinical therapeutic agent faces several limitations. The main restrictions are source variability, extraction difficulty, small molecular entity isolation (Li et al., 2022), poor solubility, and low bioavailability (Zhao, Diaby, et al., 2022). These last two factors are the most limiting since the solubility is considered the prerequisite for the therapeutic effect of drugs (Li et al., 2022).

In addition to camellia lipidś therapeutic potential, these lipids can also be used as a drug delivery system for different kinds of drugs (Li et al., 2022; Wang et al., 2021). For example, lipid fraction from *C. oleifera* successfully delivered *Mosla chinensis* essential oil in a silica-stabilized emulsion system (Li et al., 2022). In addition, this lipid fraction can also be used as an injectable solvent and ointment matrix, as listed in the Chinese Pharmacopoeia (Chinese Pharmacopoeia Commission, 2015; Li et al., 2022). However, many studies are needed to verify the possible existence of undesirable/unwanted side effects due to the interactive effects of the bioactive substances with the lipids of camellias (Li et al., 2022).

5.2. Co-products

Producing lipid extracts and/or oils from camellia seeds generates a series of co-products (Fig. 2) that can be used for other purposes. The main co-products include fruit shells and seed cakes (Li et al., 2022; Robards et al., 2009). Of these, the peel is the one that currently has a more limited use, being used almost exclusively as a source of active carbon or fertilizer. Nowadays it is also possible to find health products developed from these shells (Quan et al., 2022). As for the cake, it is a much more exploited co-product. Firstly, it is subjected to an extraction of the remaining lipids (Li et al., 2014; Robards et al., 2009; Yu et al., 2013). Later, it is subjected to other extractions to obtain bioactive compounds such as saponins, proteins, phenolic compounds, polysaccharides, tannins, and alkaloids (Zhu et al., 2018). For example, in a study carried out with cakes of *C. japonica*, six norolean triterpenoids were isolated. These compounds were shown to have neuroprotective (including prevention of the development of Alzheimer's disease) and anti-inflammatory effects (Cho et al., 2020).

Saponins represent 15%–20% content in the seed cake of *C. oleifera* (Liu et al., 2016). These compounds have raised considerable interest for their health-promoting effects (Chen et al., 2015) and are effective as natural surfactants beneficial for soil remediation Yu & He, 2018). Moreover, tea saponins can also beneficially impact the environment by manipulating rumen fermentation and microbial ecosystems of livestock to decrease nitrogen and methane emissions (Liu, Liang, et al., 2019).

The remaining seed cakes are also rich in proteins (14–20%) with proportional equilibria of amino acids (Yao et al., 2019). These proteins are mainly extracted by alkali-soluble acid precipitation (Liu et al., 2017). This extraction technique is simple, but its yield is relatively low (44.57%) (He et al., 2019). Through the coupled use of enzymes the yield can be increased up to 80.83% (Li et al., 2022). Therefore, the co-products obtained after lipid extraction are valuable sources of compounds of interest for different industries (*e.g.,* food, feed, or cosmetics).

6. Conclusions

In recent decades, the camellia lipid industry has seen exponential growth. This is due to the high quality of lipids, as well as the beneficial properties associated with this product. Different techniques can be used to obtain lipid extracts. Those traditionally used are a source of controversy; despite being the most installed in the industry, they have a negative impact on the environment. Accordingly, new and more ecological extraction techniques are developing in recent decades. These extraction processes must be combinations of pretreatment, efficient extraction, and adequate refining methods, which allow the maximum use of co-products (mainly shells and cakes). These co-products are a source of bioactive compounds and proteins, thus increasing the profitability of the process. However, most emerging techniques are still used on a laboratory scale, so further studies are needed.

CRediT authorship contribution statement

Antia G. Pereira: Conceptualization, Methodology, Formal analysis, Investigation, Visualization, Supervision. Maria Carpena: Conceptualization, Methodology, Formal analysis, Visualization, Supervision. Lucia Cassani: Conceptualization, Methodology. Franklin Chamorro:

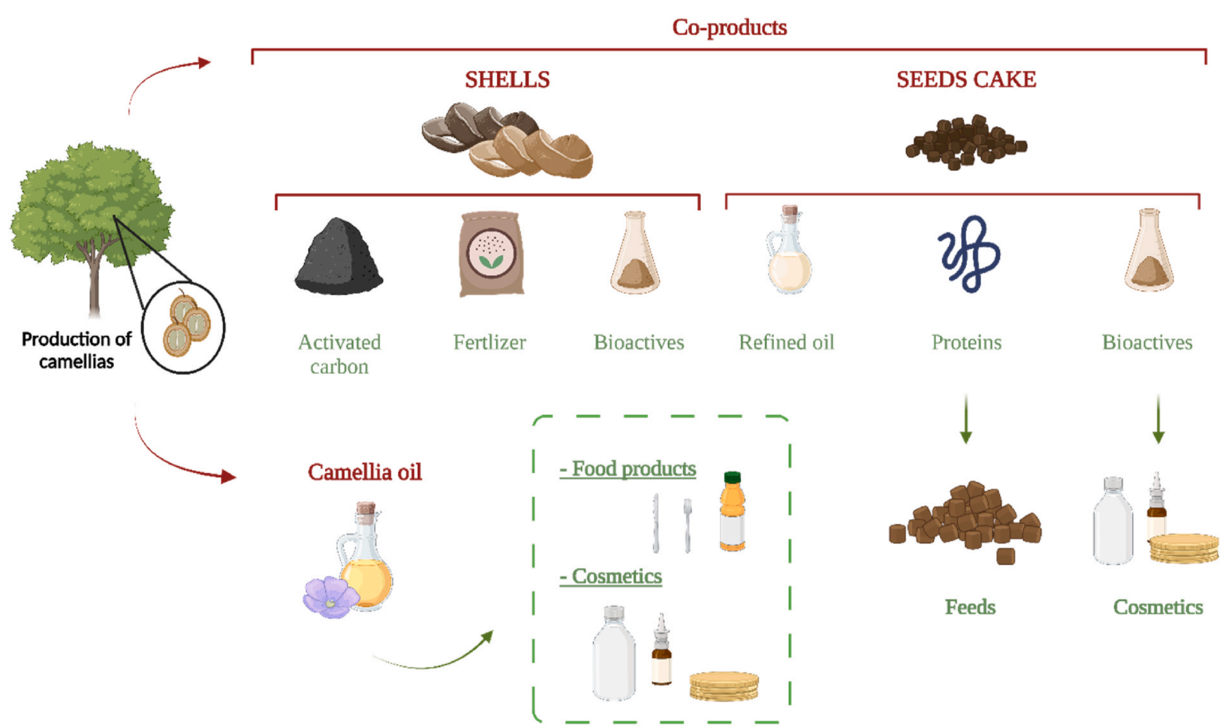


Fig. 2. Products obtained from camellias seed. Created with Biorender.

Conceptualization, Methodology. Jesus Simal-Gandara: Conceptualization, Methodology, Formal analysis, Investigation, Visualization, Supervision. Miguel A. Prieto: Conceptualization, Methodology, Formal analysis, Investigation, Visualization, Supervision.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

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

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References

Abe, H., Miura, H., & Motonaga, Y. (2021). Quantitative classification of *Camellia japonica* and *Camellia rusticana* (Theaceae) based on leaf and flower morphology. *Plant Diversity, 43*(3), 216–224. https://doi.org/10.1016/j.pld.2020.12.009

Ahangari, H., King, J. W., Ehsani, A., & Yousefi, M. (2021). Supercritical fluid extraction of seed oils – a short review of current trends. *Trends in Food Science & Technology, 111*, 249–260. https://doi.org/10.1016/J.TIFS.2021.02.066

Allen, C. (2015). Thermal degradation and biodiesel production using *Camellia oleifera* seed oil. *Journal of Chemical Information and Modeling, 53*(9), 1689–1699.

Anna, & Wypych, G. (2014). Generally recognized as safe, GRAS, solvents. In *Databook of green solvents* (pp. 204–236). Elsevier. https://doi.org/10.1016/b978-1-895198-82-9.50010-5.

Anvar, S. (2009). Ultrasound-assisted extraction of oil from tea seeds. *Journal of Food Lipids, 16*(4), 465–474. https://doi.org/10.1111/j.1745-4522.2009.01159.x

Baldermann, S., Blagojević, L., Frede, K., Klopsch, R., Neugart, S., Neumann, A., … Schreiner, M. (2016). Are neglected plants the food for the future? *Critical Reviews in Plant Sciences, 35*(2), 106–119. https://doi.org/10.1080/07352689.2016.1201399

Barreiro, R., Rodríguez-Solana, R., Alonso, L., Salinero, C., Sánchez, J. I. L., & Pérez-Santín, E. (2021). Fast1h-nmr species differentiation method for camellia seed oils applied to Spanish ornamentals plants. Comparison with traditional gas chromatography. *Plants, 10*(10). https://doi.org/10.3390/plants10101984, 1984.

Bhuyan, L. P., & Mahanta, P. K. (1989). Studies on fatty acid composition in tea *Camellia sinensis*. *Journal of the Science of Food and Agriculture, 46*(3), 325–330. https://doi.org/10.1002/JSFA.2740460310

Borgohain, A., Konwar, K., Buragohain, D., Varghese, S., Kumar Dutta, A., Paul, R. K., … Karak, T. (2020). Temperature effect on biochar produced from tea (*Camellia sinensis L.*) pruning litters: A comprehensive treatise on physico-chemical and statistical approaches. *Bioresource Technology, 318*, Article 124023. https://doi.org/10.1016/j.biortech.2020.124023

Carreira-Casais, A., Carpena, M., Pereira, A. G., Chamorro, F., Soria-Lopez, A., Perez, P. G., … Prieto, M. A. (2021). Critical variables influencing the ultrasound-assisted extraction of bioactive compounds—a review. *Chemistry Proceedings, 5*(1), 50. https://doi.org/10.3390/csac2021-10562

Carreira-Casais, A., Otero, P., Garcia-Perez, P., Garcia-Oliveira, P., Pereira, A. G., Carpena, M., … Prieto, M. A. (2021). Benefits and drawbacks of ultrasound-assisted extraction for the recovery of bioactive compounds from marine algae. *International Journal of Environmental Research and Public Health, 18*(17), 9153. https://doi.org/10.3390/ijerph18179153

Chemat, F., Vian, M. A., & Cravotto, G. (2012). Green extraction of natural products: Concept and principles. *International Journal of Molecular Sciences, 13*(7), 8615–8627. https://doi.org/10.3390/ijms13078615

Chen, Z. M., & Chen, L. (2012). Delicious and healthy tea: An overview. In *Advanced topics in science and Technology in China* (pp. 1–11). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-642-31878-8_1.

Chen, D., Ding, Y., Chen, G., Sun, Y., Zeng, X., & Ye, H. (2020). Components identification and nutritional value exploration of tea (*Camellia sinensis* L.) flower extract: Evidence for functional food. *Food Research International, 132*, Article 109100. https://doi.org/10.1016/j.foodres.2020.109100

Cheng, X., Yang, T., Wang, Y., Zhou, B., Yan, L., Teng, L., … Zhang, D. (2018). New method for effective identification of adulterated Camellia oil basing on *Camellia oleifera* specific DNA. *Arabian Journal of Chemistry, 11*(6), 815–826. https://doi.org/10.1016/J.ARABJC.2017.12.025

Chen, J., Jiang, Q. D., Chai, Y. P., Zhang, H., Peng, P., & Yang, X. X. (2016). Natural terpenes as penetration enhancers for transdermal drug delivery. *Molecules, 21*(12), 1709. https://doi.org/10.3390/molecules21121709

Chen, Z., Mei, X., Jin, Y., Kim, E. H., Yang, Z., & Tu, Y. (2014). Optimisation of supercritical carbon dioxide extraction of essential oil of flowers of tea (*Camellia sinensis L.*) plants and its antioxidative activity. *Journal of the Science of Food and Agriculture, 94*(2), 316–321. https://doi.org/10.1002/jsfa.6260

Chen, L., Tai, W. C. S., & Hsiao, W. L. W. (2015). Dietary saponins from four popular herbal tea exert prebiotic-like effects on gut microbiota in C57BL/6 mice. *Journal of Functional Foods, 17*, 892–902. https://doi.org/10.1016/J.JFF.2015.06.050

Chen, Y., Zhou, B., Li, J., Tang, H., Zeng, L., Chen, Q., … Tang, J. (2021). Effects of long-term non-pruning on main quality constituents in 'dancong' tea (*Camellia sinensis*) leaves based on proteomics and metabolomics analysis. *Foods, 10*(11), 2649. https://doi.org/10.3390/FOODS10112649/S1

Chinese Pharmacopoeia Commission. (2015). *Chinese Pharmacopoeia*. Beijing, China: China Medical Science Press.

Cho, H. M., Ha, T. K. Q., Doan, T. P., Dhodary, B., An, J. P., Lee, B. W., … Oh, W. K. (2020). Neuroprotective effects of triterpenoids from *Camellia japonica* against amyloid β-induced neuronal damage. *Journal of Natural Products, 83*(7), 2076–2086. https://doi.org/10.1021/acs.jnatprod.9b00964

Chou, T. Y., Lu, Y. F., Inbaraj, B. S., & Chen, B. H. (2018). Enhancement of antioxidative activity and cardiovascular protection in hamsters by camellia oil and soybean–camellia blended oil. *Nutrition, 51–52*, 86–94. https://doi.org/10.1016/j.nut.2017.12.011

Ciau Solís, N., Rosado Rubio, G., Chel Guerrero, L., & Betancur Ancona, D. (2016). Aplicación de métodos enzimáticos para la extracción de aceite de chía (*Salvia hispánica* L). *Journal of Negative & No Positive Results, 1*(2), 50–55. https://doi.org/10.19230/jonnpr.2016.1.2.971

Das, S., Nadar, S. S., & Rathod, V. K. (2021). Integrated strategies for enzyme assisted extraction of bioactive molecules: A review. *International Journal of Biological Macromolecules, 191*, 899–917. https://doi.org/10.1016/j.ijbiomac.2021.09.060

Delazar, A., Nahar, L., Hamedeyazdan, S., & Sarker, S. D. (2012). Microwave-assisted extraction in natural products isolation. *Methods in Molecular Biology, 864*, 89–115. https://doi.org/10.1007/978-1-61779-624-1_5

Djilani, A., & Dicko, A. (2012). The therapeutic benefits of essential oils. In *Nutrition, well-being and health* (pp. 155–178). InTech. https://doi.org/10.5772/25344.

Dong, C., An, T., Yang, M., Yang, C., Liu, Z., Li, Y., … Fan, S. (2022). Quantitative prediction and visual detection of the moisture content of withering leaves in black tea (*Camellia sinensis*) with hyperspectral image. *Infrared Physics & Technology, 123*, Article 104118. https://doi.org/10.1016/j.infrared.2022.104118

Du, S., Liu, M., Dong, F., Yue, C., Ruan, J., Cao, H., & Zhang, Q. (2022). Lipidomics analysis of tea leaves cultured in hydroponics reveals that high nitrogen application decreases tea plant resistance to ultraviolet radiation. *Horticulturae, 8*(8). https://doi.org/10.3390/horticulturae8080724

Echave, J., Pereira, A. G., Carpena, M., Prieto, M. A., & Simal-Gándara, J. (2020). Capsicum seeds as a source of bioactive compounds: Biological properties, extraction systems, and industrial application. In *IntechOpen (p. 37*. Retrieved from https://www.intechopen.com/books/advanced-biometric-technologies/liveness-detection-in-biometrics.

El Chami, A., Conte, P., Hassoun, G., & Piga, A. (2023). Effect of region of cultivation, tree age, and harvest time on the quality of Lebanese virgin olive oil. *Italian Journal of Food Science, 35*(1), 57–71. https://doi.org/10.15586/ijfs.v35i1.2286

Esclapez, M. D., García-Pérez, J. V., Mulet, A., & Cárcel, J. A. (2011). Ultrasound-assisted extraction of natural products. *Food Engineering Reviews, 3*(2), 108–120. https://doi.org/10.1007/s12393-011-9036-6

Fang, X., Du, M., Luo, F., & Jin, Y. (2015). Physicochemical properties and lipid composition of camellia seed oil (*Camellia oleifera* abel.) extracted using different methods. *Food Science and Technology Research, 21*(6), 779–785. https://doi.org/10.3136/fstr.21.779

Fang, X., Fei, X., Sun, H., & Jin, Y. (2016). Aqueous enzymatic extraction and demulsification of camellia seed oil (*Camellia oleifera* Abel.) and the oil's physicochemical properties. *European Journal of Lipid Science and Technology, 118*(2), 244–251. https://doi.org/10.1002/ejlt.201400582

Fang, X. Z., Wang, K. L., Yao, X. H., & Wang, Y. P. (2010). Aqueous enzymatic extraction of oil-tea camellia (*Camellia oleifera*) seed oil. *Forest Research, 23*(5), 778–781.

Feás, X., Estevinho, L. M., Salinero, C., Vela, P., Sainz, M. J., Vázquez-Tato, M. P., & Seijas, J. A. (2013). Triacylglyceride, antioxidant and antimicrobial features of virgin *Camellia oleifera, C. reticulata* and *C. sasanqua* oils. *Molecules, 18*(4), 4573–4587. https://doi.org/10.3390/molecules18044573

Fei, X. (2011). Study on current status, problems and countermeasures of oil-tea camellia seeds oil processing industry. *Sci. Technol. Food Ind., 32*, 449–452.
Feng, S., Tang, M., Jiang, Z., Ruan, Y., Liu, L., Kong, Q., … Ding, C. (2022). Optimization of extraction process, structure characterization, and antioxidant activity of polysaccharides from different parts of *Camellia oleifera* abel. *Foods, 11*(20), 3185. https://doi.org/10.3390/foods11203185
Fernandes, L., Ramalhosa, E., Pereira, J. A., Saraiva, J. A., & Casal, S. (2020). Borage, camellia, centaurea and pansies: Nutritional, fatty acids, free sugars, vitamin E, carotenoids and organic acids characterization. *Food Research International, 132*, Article 109070. https://doi.org/10.1016/j.foodres.2020.109070
Food and Agriculture Organisation of United Nations. (2022). *International tea market: Market situation, prospects and emerging issues*.
Food and Agriculture Organization of The United Nations (FAO). (2014). *World tea production and trade current and future development 2014*. Retrieved from www.fao.org/publications.
Frančáková, H., Ivanišová, E., Dráb, Š., Krajčovič, T., Tokár, M., Mareček, J., & Musilová, J. (2015). Composition of fatty acids in selected vegetable oils. *Potravinarstvo, 9*(1), 538–542. https://doi.org/10.5219/556
Garcia-Jares, C., Sanchez-Nande, M., Lamas, J. P., & Lores, M. (2017). Profiling the fatty acids content of ornamental camellia seeds cultivated in galicia by an optimized matrix solid-phase dispersion extraction. *Bioengineering, 4*(4), 87. https://doi.org/10.3390/bioengineering4040087
García-Pérez, P., Miras-Moreno, B., Lucini, L., & Gallego, P. P. (2021). The metabolomics reveals intraspecies variability of bioactive compounds in elicited suspension cell cultures of three *Bryophyllum* species. *Industrial Crops and Products, 163*(November 2020), Article 113322. https://doi.org/10.1016/j.indcrop.2021.113322
German, J. B., & Dillard, C. J. (2004). Saturated fats: What dietary intake?. In *American journal of clinical nutrition*. American Society for Nutrition. https://doi.org/10.1093/ajcn/80.3.550.
Giuffrè, A. M., Capocasale, M., Zappia, C., & Poiana, M. (2017). Influence of high temperature and duration of heating on the sunflower seed oil properties for food use and bio-diesel production. *Journal of Oleo Science, 66*(11), 1193–1205. https://doi.org/10.5650/jos.ess17109
Guo, L., Du, Z. hua, Wang, Z., Lin, Z., Guo, Y. ling, & Chen, M. jie (2020). Location affects fatty acid composition in *Camellia sinensis* cv Tieguanyin fresh leaves. *Journal of Food Science and Technology, 57*(1), 96. https://doi.org/10.1007/S13197-019-04034-8
Haro Bailón, A. de, Obregón, S., Río Celestino, M. del, Mansilla, P., & Salinero, M. C. (2014). Variability in seed storage components (protein, oil and fatty acids) in a Camellia germplasm collection. In *Proceedings of the international camellia congress* (pp. 302–309). Retrieved from https://digital.csic.es/handle/10261/126721.
He, W., Chen, J., Zhao, Y., & Cao, X. (2019). Study on the extraction process of protein from *Camellia oleifera* seed cake. *Journal of Henan University of Technology (Natural Science Edition), 40*, 13–19.
Hicks, A. (2009). Review of global tea production and the impact on industry of the asian economic situation. November 2008 *AU Journal of Technology, 12*, 251–264. Retrieved from http://www.assumptionjournal.au.edu/index.php/aujournaltechnology/article/view/1174.
Huang, S., Hu, Y., Li, F., Jin, W., Godara, V., & Wu, B. (2019). Optimization of mechanical oil extraction process from *Camellia oleifera* seeds regarding oil yield and energy consumption. *Journal of Food Process Engineering, 42*(6), Article e13157. https://doi.org/10.1111/jfpe.13157
Huang, T., Zhou, W., Ma, X., Jiang, J., Zhang, F., Zhou, W., … Cui, G. (2021). Oral administration of camellia oil ameliorates obesity and modifies the gut microbiota composition in mice fed a high-fat diet. *FEMS Microbiology Letters, 368*(10), 63. https://doi.org/10.1093/femsle/fnab063
Hu, B., Li, C., Qin, W., Zhang, Z., Liu, Y., Zhang, Q., … Liu, S. (2019). A method for extracting oil from tea (*Camelia sinensis*) seed by microwave in combination with ultrasonic and evaluation of its quality. *Industrial Crops and Products, 131*, 234–242. https://doi.org/10.1016/j.indcrop.2019.01.068
Innis, S. M. (2007). Fatty acids and early human development. *Early Human Development, 83*(12), 761–766. https://doi.org/10.1016/j.earlhumdev.2007.09.004
International Camellia Society. (2021). In *International camellia society*. Retrieved May 18, 2021, from https://internationalcamellia.org/.
International Olive Council. (2022). *Trade standard for olive oils and olive pomace oils COI*. /T.15/NC No. 3/Rev. 19, from https://www.internationaloliveoil.org/wp-content/uploads/2022/12/Norme-comerciale-REV-19_ENK.pdf.
Ivanov, D., Čolović, R., Bera, O., Lević, J., & Sredanović, S. (2011). Supercritical fluid extraction as a method for fat content determination and preparative technique for fatty acid analysis in mesh feed for pigs. *European Food Research and Technology, 233*(2), 343–350. https://doi.org/10.1007/s00217-011-1521-x
Jeon, A.-L., Jun, N. J., Shaowei, Y., Song, Y. keun, Suh, I. S., & Byun, S. Y. (2012). *Study on essential oil from Camellia japonica L. Seed using supercritical fluid extraction. 한국생물공학회 학술대회, 256–256*. Retrieved from https://www.earticle.net/Article/A174861.
Jimenez-Lopez, C., Carpena, M., Lourenço-Lopes, C., Gallardo-Gomez, M., Lorenzo, J. M., Barba, F. J., … Simal-Gandara, J. (2020). Bioactive compounds and quality of extra virgin olive oil. *Foods, 9*(8), 1014. https://doi.org/10.3390/foods9081014
Jiménez-Moreno, N., Esparza, I., Bimbela, F., Gandía, L. M., & Ancín-Azpilicueta, C. (2020). Valorization of selected fruit and vegetable wastes as bioactive compounds: Opportunities and challenges. *Critical Reviews in Environmental Science and Technology, 50*(20), 2061–2108. https://doi.org/10.1080/10643389.2019.1694819
Joshi, R., Poonam, & Gulati, A. (2011). Biochemical attributes of tea flowers (*Camellia sinensis*) at different developmental stages in the Kangra region of India. *Scientia Horticulturae, 130*(1), 266–274. https://doi.org/10.1016/J.SCIENTA.2011.06.007
Kim, J., Choi, K., & Chung, D. S. (2012). Sample preparation for capillary electrophoretic applications. *Comprehensive Sampling and Sample Preparation, 3*, 701–721. https://doi.org/10.1016/B978-0-12-381373-2.00110-1. Elsevier Inc.
Kim, B.-S., Choi, O.-J., & Shim, K.-H. (2005). Properties of chemical components of *Camellia japonica* L. Loaves according to picking time. *Journal of the Korean Society of Food Science and Nutrition, 34*(5), 681–686. https://doi.org/10.3746/jkfn.2005.34.5.681
Koch, W., Zagórska, J., Marzec, Z., & Kukula-Koch, W. (2019). *November 24). Applications of tea (Camellia sinensis) and its active constituents in cosmetics. Molecules*. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/molecules24234277
Kong, Y., Wang, G., Wang, X., Wang, T., Shen, J., Zhang, A., … Zhang, Y. (2021). Essential oils from the dropped flowers of *Camellia japonica*: Extraction optimization, chemical profile and antibacterial property. *American Journal of Biochemistry and Biotechnology, 17*(1), 40–49. https://doi.org/10.3844/ajbbsp.2021.40.49
Kostik, V., Memeti, S., & Bauer, B. (2013). Fatty acid composition of edible oils and fats. *Journal of Hygienic Engineering and Design, 4*, 112–116.
Lal, J. J., Sreeranjit Kumar, C. V., & Indira, M. (2003). Coconut palm. In *Encyclopedia of food sciences and nutrition* (pp. 1464–1475). Elsevier. https://doi.org/10.1016/b0-12-227055-x/00263-7.
Laranjeira, T., Costa, A., Faria-Silva, C., Ribeiro, D., Ferreira de Oliveira, J. M. P., Simões, S., & Ascenso, A. (2022). Sustainable valorization of tomato by-products to obtain bioactive compounds: Their potential in inflammation and cancer management. *Molecules, 27*(5). https://doi.org/10.3390/molecules27051701
Lavenburg, V. M., Rosentrater, K. A., Jung, S., Hernández-Ledesma, B., & Claro Da Silva, R. (2021). Extraction methods of oils and phytochemicals from seeds and their environmental and economic impacts. *Processes, 2021*, 1839. https://doi.org/10.3390/PR9101839, 1839, 9(10.
Lee, S. Y., Bae, C. S., Seo, N. S., Na, C. S., Yoo, H. Y., Oh, D. S., … Park, D. H. (2019). *Camellia japonica* oil suppressed asthma occurrence via GATA-3 & IL-4 pathway and its effective and major component is oleic acid. *Phytomedicine, 57*, 84–94. https://doi.org/10.1016/j.phymed.2018.12.004
Lee, C. P., & Yen, G. C. (2006). Antioxidant activity and bioactive compounds of tea seed (*Camellia oleifera* Abel.) oil. *Journal of Agricultural and Food Chemistry, 54*(3), 779–784. https://doi.org/10.1021/jf052325a
Liang, H., Hao, B. Q., Chen, G. C., Ye, H., & Ma, J. (2017). Camellia as an oilseed crop. *HortScience, 52*(4), 488–497. https://doi.org/10.21273/HORTSCI11570-16
Li, Z., Jiang, X., Liu, H., Yao, Z., Liu, A., & Ming, L. (2022). Evaluation of hydrophilic and hydrophobic silica particles on the release kinetics of essential oil pickering emulsions. *ACS Omega, 7*(10), 8651–8664. https://doi.org/10.1021/acsomega.1c06666
Li, Z., Jiang, X., Yao, Z., Chen, F., Zhu, L., Liu, H., & Ming, L. (2022). Chitosan functionalized cellulose nanocrystals for stabilizing Pickering emulsion: Fabrication, characterization and stability evaluation. *Colloids and Surfaces A: Physicochemical and Engineering Aspects, 632*, Article 127769. https://doi.org/10.1016/j.colsurfa.2021.127769
Li, S., & Liu, X. (2011). Cold-pressed oil extraction of camellia seeds. *ICAE 2011 Proceedings: 2011 International Conference on New Technology of Agricultural Engineering, 2007*(119), 135–138. https://doi.org/10.1109/ICAE.2011.5943767
Li, Z., Liu, A., Du, Q., Zhu, W., Liu, H., Naeem, A., & Ming, L. (2022). *Bioactive substances and therapeutic potential of camellia oil: An overview*. *Food Bioscience*. Elsevier. https://doi.org/10.1016/j.fbio.2022.101855
Li, S., Liu, X., Zhang, Y., & Liu, Q. (2014). Pilot-plant-scale test of cold-pressed oil extraction with twin-screw pressing for camellia seeds. *Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering, 30*(19), 300–308. https://doi.org/10.3969/j.issn.1002-6819.2014.19.036
Li, G., Ma, L., Yan, Z., Zhu, Q., Cai, J., Wang, S., … Deng, S. (2022). Extraction of oils and phytochemicals from *Camellia oleifera* seeds: Trends, challenges, and innovations. *Processes, 10*(8), 1489. https://doi.org/10.3390/pr10081489
Liu, Y., Liang, Y., Li, X., & Li, J. (2019). Optimization of key techniques for ethanol extraction of camellia seed oil by response surface experiment. *SDRP Journal of Food Science & Technology, 4*(2), 652–658. https://doi.org/10.25177/jfst.4.2.ra.475
Liu, J., Li, X., Xiang, C., Liu, L., Feng, S., & Ding, C. (2017). Functional properties of camellia oleifera seed-cake protein and antioxidant activity of its enzymatic hydrolysate. *Journal of the Chinese Cereals and Oils Association, 32*, 40–46.
Liu, Y., Li, Z., Xu, H., & Han, Y. (2016). Extraction of saponin from *Camellia oleifera* abel cake by a combination method of alkali solution and acid isolation. *Journal of Chemistry*, 1–8. https://doi.org/10.1155/2016/6903524, 2016.
Liu, Y., Ma, T., Chen, D., Zhang, N., Si, B., Deng, K., … Diao, Q. (2019). Effects of tea saponin supplementation on nutrient digestibility, methanogenesis, and ruminal microbial flora in dorper crossbred Ewe. *Animals, 9*(1), 29. https://doi.org/10.3390/ani9010029
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. *Scientific Reports, 12*(1), Article 16554. https://doi.org/10.1038/s41598-022-20576-y
Louadj, J., & Giuffrè, A. M. (2010). Analytical characteristics of olive oil produced with three different processes in Algeria. *Rivista Italiana Delle Sostanze Grasse, 87*(3), 186–195.
Mancini, A., Imperlini, E., Nigro, E., Montagnese, C., Daniele, A., Orrù, S., & Buono, P. (2015). Biological and nutritional properties of palm oil and palmitic acid: Effects on health. *Molecules. MDPI AG*. https://doi.org/10.3390/molecules200917339. September 1.
Mandal, S. C., Mandal, V., & Das, A. K. (2015). Extraction of botanicals. In *Essentials of botanical extraction* (pp. 63–82). Elsevier. https://doi.org/10.1016/b978-0-12-802325-9.00005-7.

Marhamati, M., Kakhaki, K. K., & Rezaie, Z. (2020). Advance in ultrasound-assisted extraction of edible oils: A review. *J Nutr Fast Health, 8*(4), 220–230. https://doi.org/10.22038/JNFH.2020.51138.1288

Ma, J., Ye, H., Rui, Y., Chen, G., & Zhang, N. (2011). Fatty acid composition of *Camellia oleifera* oil. *Journal Fur Verbraucherschutz Und Lebensmittelsicherheit, 6*(1), 9–12. https://doi.org/10.1007/s00003-010-0581-3

Meng, X., Ge, H., Ye, Q., Peng, L., Wang, Z., & Jiang, L. (2018). Efficient and response surface optimized aqueous enzymatic extraction of *Camellia oleifera* (tea seed) oil facilitated by concurrent calcium chloride addition. *Journal of the American Oil Chemists' Society, 95*(1), 29–37. https://doi.org/10.1002/aocs.12009

Meng, X. H., Li, N., Zhu, H. T., Wang, D., Yang, C. R., & Zhang, Y. J. (2019). Plant resources, chemical constituents, and bioactivities of tea plants from the genus camellia section thea. *Journal of Agricultural and Food Chemistry, 67*(19), 5318–5349. https://doi.org/10.1021/ACS.JAFC.8B05037/ASSET/IMAGES/LARGE/JF-2018-050376_0011 (JPEG).

Nakamura, N., Mori, M., & Suzuki, H. (1984). Chemical characterization of the callose plug isolated from *Camellia japonica* pollen tube. *Plant and Cell Physiology, 25*(2), 233–238. https://doi.org/10.1093/oxfordjournals.pcp.a076706

Namita, P., Mukesh, R., & Vijay, K. J. (2012). *Camellia sinensis* (green tea): A review. *Global Journal of Pharmacology, 6*(2), 52–59.

Ni, Z. J., Liu, X., Xia, B., Hu, L. T., Thakur, K., & Wei, Z. J. (2021). Effects of sugars on the flavor and antioxidant properties of the Maillard reaction products of camellia seed meals. *Food Chemistry X, 11*, Article 100127. https://doi.org/10.1016/J.FOCHX.2021.100127

Orsavova, J., Misurcova, L., Vavra Ambrozova, J., Vicha, R., & Mlcek, J. (2015). Fatty acids composition of vegetable oils and its contribution to dietary energy intake and dependence of cardiovascular mortality on dietary intake of fatty acids. *International Journal of Molecular Sciences, 16*(6), 12871–12890. https://doi.org/10.3390/ijms160612871

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

Pereira, A. G., Fraga-Corral, M., Garciá-Oliveira, P., Jimenez-Lopez, C., Lourenço-Lopes, C., Carpena, M., … Simal-Gandara, J. (2020). Culinary and nutritional value of edible wild plants from northern Spain rich in phenolic compounds with potential health benefits. In *Food and function. Royal society of chemistry*. https://doi.org/10.1039/d0fo02147d

Pereira, A. G., Garcia-Perez, P., Cassani, L., Chamorro, F., Cao, H., Barba, F. J., … Prieto, M. A. (2022). *Camellia japonica*: A phytochemical perspective and current applications facing its industrial exploitation. *Food Chemistry X, 13*, Article 100258. https://doi.org/10.1016/j.fochx.2022.100258

Pereira, A. G., Jimenez-Lopez, C., Fraga, M., Lourenço-Lopes, C., García-Oliveira, P., Lorenzo, J. M., … Simal-Gandara, J. (2020). Extraction, properties, and applications of bioactive compounds obtained from microalgae. *Current Pharmaceutical Design, 26*(16), 1929–1950. https://doi.org/10.2174/1381612826666200403172206

Pykett, M. A., Craig, A. H., Galley, E., Smith, C., & Long, S. P. (2007). *Skincare composition against free radicals. 27 march 2007.* U.S. Patent 07195787 (The Boots Company PLC).

Qian, J., Zhao, X., Zhao, C., Yang, H., Gou, L., Wang, W., & Guo, H. (2021). Pretreatment camellia seeds by protease and application to extraction of camellia oil. *European Journal of Lipid Science and Technology, 123*(1), Article 2000223. https://doi.org/10.1002/ejlt.202000223

Quan, W., Wang, A., Gao, C., & Li, C. (2022). May 24). Applications of Chinese *Camellia oleifera* and its by-products: A review. In *Frontiers in chemistry. Frontiers media S.A*. https://doi.org/10.3389/fchem.2022.921246

Rajaei, A., Barzegar, M., & Yamini, Y. (2005). Supercritical fluid extraction of tea seed oil and its comparison with solvent extraction. *European Food Research and Technology, 220*(3–4), 401–405. https://doi.org/10.1007/s00217-004-1061-8

Ramachandran, G., Rajivgandhi, G. N., Murugan, S., Alharbi, N. S., Kadaikunnan, S., Khaled, J. M., … Li, W. J. (2020). Anti-carbapenamase activity of *Camellia japonica* essential oil against isolated carbapenem resistant klebsiella pneumoniae (MN396685). *Saudi Journal of Biological Sciences, 27*(9), 2269–2279. https://doi.org/10.1016/j.sjbs.2020.06.044

Rawa-Adkonis, M., Wolska, L., & Namieśnik, J. (2006). Analytical procedures for PAH and PCB determination in water samples. *Critical Reviews in Analytical Chemistry, 36*(2), 63–72. https://doi.org/10.1080/10408340600713645

Rivas-García, L., Navarro-Hortal, M. D., Romero-Márquez, J. M., Forbes-Hernández, T. Y., Varela-López, A., Llopis, J., … Quiles, J. L. (2021). November 1). Edible flowers as a health promoter: An evidence-based review. In *Trends in food science and Technology*. Elsevier. https://doi.org/10.1016/j.tifs.2020.12.007.

Robards, K., Prenzler, P., Ryan, D., & Zhong, H. (2009). *Camellia oil and tea oil. Gourmet and health-promoting specialty oils* (p. 313). https://doi.org/10.1016/B978-1-893997-97-4.50017-6. –343.

Sagan, A., Blicharz-Kania, A., Szmigielski, M., Andrejko, D., Sobczak, P., Zawiślak, K., & Starek, A. (2019). Assessment of the properties of rapeseed oil enriched with oils characterized by high content of α-linolenic acid. *Sustainability, 11*(20). https://doi.org/10.3390/su11205638

Salinero, P. M., & Corral, C. S. (2008). El aceite de camelia. *Sociedad Española de La Camelia, 13*(1), 1–5.

Salinero, C., Feás, X., Pedro Mansilla, J., Seijas, J. A., Pilar Vázquez-Tato, M., Vela, P., & Sainz, M. J. (2012). 1H-nuclear magnetic resonance analysis of the triacylglyceride composition of cold-pressed oil from *Camellia japonica*. *Molecules, 17*(6), 6716–6727. https://doi.org/10.3390/molecules17066728

Sanz, V., Flórez-Fernández, N., Domínguez, H., & Torres, M. D. (2020). Valorisation of *Camellia sinensis* branches as a raw product with green technology extraction methods. *Current Research in Food Science, 2*, 20–24. https://doi.org/10.1016/J.CRFS.2019.11.006

Savoire, R., Lanoisellé, J. L., & Vorobiev, E. (2013). Mechanical continuous oil expression from oilseeds: A review. *Food and Bioprocess Technology, 6*(1), 1–16. https://doi.org/10.1007/S11947-012-0947-X/FIGURES/8

Shevchuk, A., Megías-Pérez, R., Zemedie, Y., & Kuhnert, N. (2020). Evaluation of carbohydrates and quality parameters in six types of commercial teas by targeted statistical analysis. *Food Research International, 133*, Article 109122. https://doi.org/10.1016/J.FOODRES.2020.109122

Shi, L., Gu, Y., Wu, D., Wu, X., Grierson, D., Tu, Y., & Wu, Y. (2019). Hot air drying of tea flowers: Effect of experimental temperatures on drying kinetics, bioactive compounds and quality attributes. *International Journal of Food Science and Technology, 54*(2), 526–535. https://doi.org/10.1111/ijfs.13967

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/10.1016/J.TIFS.2020.01.005

Silva, G. L., Lee, I.-S., & Kinghorn, A. D. (1998). *Special problems with the extraction of plants* (pp. 343–363). Humana Press. https://doi.org/10.1007/978-1-59259-256-2_12

Song, D., Jaganathan, G. K., Han, Y., & Liu, B. (2017). Seed dormancy in *Camellia sinensis* L. (theaceae): Effects of cold-stratification and exogenous gibberellic acid application on germination. *Botany, 95*(2), 147–152. https://doi.org/10.1139/cjb-2016-0149

Sparr Eskilsson, C., & Björklund, E. (2000). Analytical-scale microwave-assisted extraction. *Journal of Chromatography A, 902*(1), 227–250. https://doi.org/10.1016/S0021-9673(00)00921-3

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

Tang, Z., Yang, C., Dong, X., Zhou, B., & Li, Y. (2014). Study on microwave-assisted extraction of residual oil in defatted cake of camellia using ethanol-water as solvent. *Food Research and Development, 35*, 27–30.

The American Camellia Society. (2021). *American camellia society*. Retrieved May 18, 2021, from https://www.americancamellias.com/.

Tu, X., & Chen, W. (2018). A review on the recent progress in matrix solid phase dispersion. *Molecules, 23*(11), 2767. https://doi.org/10.3390/molecules23112767

Venthodika, A., Chhikara, N., Mann, S., Garg, M. K., Sofi, S. A., & Panghal, A. (2021). Bioactive compounds of aegle marmelos L., medicinal values and its food applications: A critical review. *Phytotherapy Research, 35*(4), 1887–1907. https://doi.org/10.1002/PTR.6934

Vilkhu, K., Mawson, R., Simons, L., & Bates, D. (2008). *Applications and opportunities for ultrasound assisted extraction in the food industry–A review, 9.* Innovative Food Science & Emerging Technologies.

Wang, X., Contreras, M., del, M., Xu, D., Jia, W., Wang, L., & Yang, D. (2021). New insights into free and bound phenolic compounds as antioxidant cluster in tea seed oil: Distribution and contribution. *Lebensmittel-Wissenschaft & Technologie, 136*, Article 110315. https://doi.org/10.1016/j.lwt.2020.110315

Wang, C., Han, J., Pu, Y., & Wang, X. (2022). Tea (*Camellia sinensis*): A review of nutritional composition, potential applications, and omics research. *Applied Sciences, 2022*, 5874. https://doi.org/10.3390/APP12125874, 12, *Page 5874*, 12(12.

Wang, A., Seki, T., Yuan, D., Saso, Y., Hosoya, O., Chono, S., & Morimoto, K. (2004). Effect of camellia oil on the permeation of flurbiprofen and diclofenac sodium through rat and pig skin. *Biological and Pharmaceutical Bulletin, 27*(9), 1476–1479. https://doi.org/10.1248/bpb.27.1476

Wang, Y., Sun, D., Chen, H., Qian, L., & Xu, P. (2011). Fatty acid composition and antioxidant activity of tea (*Camellia sinensis* L.) seed oil extracted by optimized supercritical carbon dioxide. *International Journal of Molecular Sciences, 12*(11), 7708–7719. https://doi.org/10.3390/ijms12117708

Wang, Y., Yang, Z., & Wei, X. (2010). Sugar compositions, α-glucosidase inhibitory and amylase inhibitory activities of polysaccharides from leaves and flowers of *Camellia sinensis* obtained by different extraction methods. *International Journal of Biological Macromolecules, 47*(4), 534–539. https://doi.org/10.1016/j.ijbiomac.2010.07.007

Wu, X. H., & Li, L. (2011). Optimization of ultrasound-assisted extraction of oil from camellia (*Camellia oleifera* abel) seed. *Advanced Materials Research, 236–238*, 1854–1858. Trans Tech Publications Ltd https://doi.org/10.4028/www.scientific.net/AMR.236-238.1854.

Wu, H., Li, C., Li, Z., Liu, R., Zhang, A., Xiao, Z., … Deng, S. (2018). Simultaneous extraction of oil and tea saponin from *Camellia oleifera* Abel. seeds under subcritical water conditions. *Fuel Processing Technology, 174*, 88–94. https://doi.org/10.1016/j.fuproc.2018.02.014

Wu, S., Zhang, Z., Liu, R., & Huang, S. (2012). Effect of production process on benzo (a) pyrene content in camellia oil. *Advanced Materials Research, 554–556*, 1099–1102. Trans Tech Publications Ltd https://doi.org/10.4028/www.scientific.net/AMR.554-556.1099.

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

Xiao, X. S., Yuan, X. Y., Zhang, M., & Yuan, L. (2012). Study on lipids extraction in camellia cakes with microwave-assisted. *Science and Technology of Food Industry*, (18), 309–311. https://doi.org/10.13386/J.ISSN1002-0306.2012.18.045

Xin-lei, L., Ji-yuan, L., Zhen-yuan, S., Zheng-qi, F., & Heng-fu, Y. (2022). Variability of volatile components of *Camellia azalea*. *International Camellia Society, 1*, 8. Retrieved from https://internationalcamellia.org/en-us/identification-dna/c-azalea-volatile-components.

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*, 1–6. https://doi.org/10.1155/2016/3982486, 2016.

Yang, J. Y., Li, J., Wang, M., Zou, X. G., Peng, B., Yin, Y. L., & Deng, Z. Y. (2019). A novel aqueous extraction for camellia oil by emulsified oil: A frozen/thawed method. *European Journal of Lipid Science and Technology, 121*(4), Article 1800431. https://doi.org/10.1002/ejlt.201800431

Yao, G. L., He, W., Wu, Y. G., Chen, J., Hu, X. W., & Yu, J. (2019). Structure and functional properties of protein from defatted *Camellia oleifera* seed cake: Effect of hydrogen peroxide decolorization. *International Journal of Food Properties, 22*(1), 1283–1295. https://doi.org/10.1080/10942912.2019.1642355

Ye, H., Folz, J., Li, C., Zhang, Y., Hou, Z., Zhang, L., & Su, S. (2021). Response of metabolic and lipid synthesis gene expression changes in *Camellia oleifera* to mulched ecological mat under drought conditions. *The Science of the Total Environment, 795*, Article 148856. https://doi.org/10.1016/J.SCITOTENV.2021.148856

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. *Industrial Crops and Products, 161*, Article 113193. https://doi.org/10.1016/j.indcrop.2020.113193

Yu, X. L., & He, Y. (2018). Tea saponins: Effective natural surfactants beneficial for soil remediation, from preparation to application. *RSC Advances, 8*(43), Article 24312. https://doi.org/10.1039/C8RA02859A

Yu, X., Li, Q., Du, S., Zhang, R., & Xu, C. (2013). A novel process for the aqueous extraction of oil from *Camellia oleifera* seeds and its antioxidant activity. *Grasas Y Aceites, 64*(4), 407–414. https://doi.org/10.3989/gya.106412

Yu, J., Yan, H., Wu, Y., Wang, Y., & Xia, P. (2022). In *Quality evaluation of the oil of Camellia spp. foods* (p. 2221). https://doi.org/10.3390/foods11152221, 11(15.

Zhang, W. G., Zhang, D. C., & Chen, X. Y. (2012). A novel process for extraction of tea oil from *Camellia oleifera* seed kernels by combination of microwave puffing and aqueous enzymatic oil extraction. *European Journal of Lipid Science and Technology, 114*(3), 352–356. https://doi.org/10.1002/ejlt.201000304

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 Research International, 156*, Article 111159. https://doi.org/10.1016/J.FOODRES.2022.111159

Zhao, S., Diaby, M., Zheng, N., & Wang, J. (2022). Sequential action of different fiber-degrading enzymes enhances the degradation of corn stover. *Agriculture, 12*(2), 4–13. https://doi.org/10.3390/agriculture12020181

Zhao, J., Gao, P., Mu, C., Ning, J., Deng, W., Ji, D., … Yang, X. (2022). Preparation and evaluation of novel supersaturated solid dispersion of magnolol: Theme: Advancements in amorphous solid dispersions to improve bioavailability. *AAPS PharmSciTech, 23*(4), 1–17. https://doi.org/10.1208/s12249-022-02251-7

Zhou, Y., Gu, C., & Gu, H. (2012). Supercritical CO 2 extraction of tea seed oil from camellia seeds and composition analysis of tea seed oil extracts. *Advanced Materials Research, 538*(541), 2372–2376. https://doi.org/10.4028/www.scientific.net/AMR.538-541.2372.

Zhou, X., Jiang, S., Zhao, D., Zhang, J., Gu, S., Pan, Z., & Ding, Y. (2017). Changes in physicochemical properties and protein structure of surimi enhanced with camellia tea oil. *Lebensmittel-Wissenschaft & Technologie, 84*, 562–571. https://doi.org/10.1016/J.LWT.2017.03.026

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). *Lebensmittel-Wissenschaft & Technologie, 110*, 175–181. https://doi.org/10.1016/J.LWT.2019.04.075

Zhu, M. T., Shi, T., Guo, Z. Y., Liao, H. X., & Chen, Y. (2020). Comparative study of the oxidation of cold-pressed and commercial refined camellia oil during storage with 1H and 31P NMR spectroscopy. *Food Chemistry, 321*, Article 126640. https://doi.org/10.1016/j.foodchem.2020.126640

Zhu, W. F., Wang, C. L., Ye, F., Sun, H. P., Ma, C. Y., Liu, W. Y., … Zhang, J. (2018). Chemical constituents of the seed cake of *Camellia oleifera* and their antioxidant and antimelanogenic activities. *Chemistry and Biodiversity, 15*(7), Article e1800137. https://doi.org/10.1002/cbdv.201800137

李湘洲, 胡伟 (2010). 吴志平. Retrieved from https://patents.google.com/patent/CN101845362B/en.