rcfmc Revista Científica da Faculdade de Medicina de Campos
ISSN 2965-6575

Rev. Cient. Fac. Med. Campos, v. 19, n. 1, p. 35-51, jan./jun. 2024
doi: 10.29184/1980-7813.rcfmc.1028.vol.19.n1.2024
Faculdade de Medicina de Campos
https://revista.fmc.br/ojs/index.php/RCFMC

Review Article

Camellia Sinensis: a Phytochemical research

Camellia sinensis: um levantamento fitoquímico

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Keywords:
Camellia sinensis.
Catechin.
Flavonoids.
Saponins.

Palavras-chave:
Camellia sinensis.
Catequina.
Flavonoides.
Saponinas.

Received on: 11/27/2023

Accepted on: 04/16/2024

Published on: 06/28/2024

ABSTRACT

Several pharmacological activities such as antiallergic, anticarcinogenic, antidiabetic, anti-inflammatory, neuroprotective, cardiovascular risk prevention, and obesity treatment, primarily attributed to the presence of catechins and caffeine, have been attributed to the species *Camellia sinensis* (Theaceae). Considering the importance of the plant kingdom as a source of substances and/or prototypes for the discovery of new biologically active substances and the relevance of activities associated with C. sinensis, this study aimed to survey the literature on phytochemical studies of the *Camellia* sinensis species, focusing on the identification of special metabolites. A literature review was conducted, selecting relevant articles published regardless of time, in the Chemical Abstracts Service (CAS Scifinder) database, using "*Camellia sinensis*" as a descriptor and restricting the search to publications in Phytochemistry Elsevier. The survey revealed that the most studied part of the plant was the leaf, and the studies aimed mostly to identify highly polar substances due to the most commonly used extracting liquids. The main metabolites identified in the species are derived from the mixed biosynthetic route, with emphasis on the class of flavonoids, especially epigallocatechin, epigallocatechin gallate, epicatechin, epicatechin gallate, and gallocatechin. Saponins and steroids also proved to be abundant classes of special metabolites in the species. Thus, it is crucial to consider the possible risk of toxicity inherent in the use of natural products even when they present therapeutic and beneficial properties.

RESUMO

*Diversas atividades farmacológicas como antialérgicas, anticarcinogênicas, antidiabéticas, anti-inflamatórias, neuroprotetoras, de prevenção de riscos cardiovasculares e tratamento da obesidade, relacionadas, principalmente, à presença de catequinas e cafeína têm sido atribuídas à espécie Camellia sinensis (*Theaceae*). Considerando a importância do reino vegetal como fonte de substâncias e/ou protótipos para a descoberta de novas substâncias biologicamente ativas e a relevância das atividades associadas à C. sinensis, o presente trabalho objetivou o levantamento bibliográfico de estudos fitoquímicos da espécie Camellia sinensis, com foco na identificação de metabólitos especiais. Foi realizada uma revisão bibliográfica da literatura, sendo selecionados artigos relevantes, publicados, independente do tempo, na base de dados Chemical Abstracts Service (CAS*

Scifinder), utilizando" sinensis" como descritor e restringindo a pesquisa a publicações em Phytochemistry Elsevier. O levantamento revelou que a parte da planta mais estudadafoi a folha, e os estudos objetivaram, em sua maioria, identificar substâncias de alta polariadadeem função dos líquidos extratores mais utilizados. Os principais metabólitos identificadosna espécie são oriundos da rota biossintética mista, com destaque para a classe dos flavonoides, em especial epigalocatequina, epigalocatequina-galato, epicatequina, epicatequina-galato e galocatequina. Saponinas e esteroides também se revelaram como classes de metabólitos especiais abundantes na espécie. Assim, é crucial ponderar o possível risco de toxicidade inerente ao uso de produtos naturais, mesmo quando apresentam propriedades terapêuticas e benéficas.

INTRODUCTION

Camellia sinensis belongs to the genus *Camellia* L. (Theaceae), which includes evergreen shrubs or small trees with flowers and comprises more than 325 species worldwide[1].

Species of this genus have been widely used in the beverage industry as tea. Typically, *C. sinensis* leaves are consumed in unfermented form (green tea), partially fermented (oolong tea), and fully fermented (black tea)[2].

Pharmacological and phytochemical studies have revealed that *C. sinensis* is an important source of flavonoids, saponins, tannins, phenolic compounds, and triterpenoids, with these compounds found in various parts of the plant such as leaves, flowers, roots, and seeds[1]. *C. sinensis* leaves are widely used in therapy due to the presence of polyphenols, particularly catechins and their derivatives.

Several pharmacological activities have been attributed to *C. sinensis* due to these constituents, including antiallergic, anticarcinogenic, antidiabetic, anti-inflammatory, neuroprotective, and cardiovascular risk prevention activities[2]. The properties related to obesity treatment have also been attributed to catechins along with caffeine present in its composition. Catechins can stimulate metabolism, increase fat oxidation, and improve thermogenesis. Additionally, the caffeine present in the plant can help suppress appetite and increase the energy expended by the body. These properties make *C. sinensis* an ally in obesity treatment, contributing to the promotion of health and well-being[3].

Obesity is a chronic non-communicable disease that poses various health risks, including increased blood pressure, insulin resistance, and elevated blood cholesterol and triglyceride levels[4]. Affecting people of all ages, social classes, and economic levels, obesity is considered one of the biggest health challenges globally, and its prevalence is increasing at an alarming rate.

According to a study conducted by the World Obesity Federation (2023)[5], in the next 12 years, 51% of the population over five years old will be overweight, and 24% will be obese.

The occurrence of flavonoids and proanthocyanidins in the species has been the target of studies due to their antioxidant properties[6].

In the seeds and roots of *C. sinensis*, various saponins have been identified; however, few studies have pointed out the presence of these metabolites in the leaves. The immunostimulant effect has been attributed to substances of this class of metabolites capable of stimulating the immune response of the organism[1, 7].

In Brazil, the cultivation of *C. sinensis* is restricted to the Vale do Ribeira in the state of São Paulo, with most production aimed at black tea. The growing interest of the Brazilian public in green tea has led to an increase in its production. Additionally, studies indicate that Brazilian tea has a higher quantity of phenolic compounds compared to teas from other countries, attributed to the climatic and soil characteristics. However, research on Brazilian green tea is still scarce compared to studies conducted in other green tea-producing countries[8].

Considering the importance of the plant kingdom as a source of substances and/or prototypes for the discovery of new biologically active substances and the relevance of the activities associated with the species in question, this study aimed to survey the literature on phytochemical studies of the *Camellia sinensis* species (green tea), focusing on the identification of special metabolites, also known as secondary metabolites.

MATERIAL AND METHODS

This is a literature review study, with the bibliographic survey conducted in the Chemical Abstracts Service (CAS Scifinder) database using "*Camellia sinensis*" as a descriptor and restricting the search to publications in Phytochemistry Elsevier, a peer-reviewed scientific journal in the field of phytochemistry. In this process, studies describing special metabolites identified in *C. sinensis* were included. Studies that did not address the central theme of this work, not describing special metabolites identified in *C. sinensis*, were excluded. After the survey of the articles, an analysis process was carried out in three stages: pre-analysis involving the reading of the articles included in the research; exploration of the material to identify and extract the desired information; and finally, grouping the results for interpretation and discussion. The data collected included the part of the plant studied, the extract obtained, the chemical constituents identified, the year of publication, and the country of origin. The substances identified in the *C. sinensis* species were classified by pharmacognostic class.

Data tabulation were performed using Microsoft Excel 2010®, and the results were presented and discussed based on the profile of the publications and the phytochemical profile presented by *C. sinensis* studies.

This manuscript was translated with the assistance of ChatGPT, an AI language model developed by OpenAI.

RESULTS AND DISCUSSION

The publication of these articles was more prevalent between 1990 and 2000, totaling 54.54% (**Figure 2A**). This significant percentage of publications in this period may be related to the prosperous phase for the development of new drugs that marked the post-war period, characterized by technological advancements essential in the isolation and structural elucidation of secondary metabolites that serve as raw material or prototypes for the development of new drugs[9, 10].

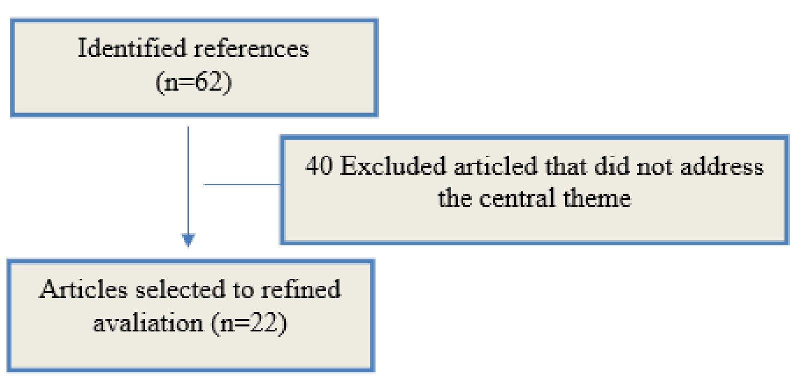


Figure 1 - Flowchart of the survey and selection of documents for review

The 1970s accounted for 18.18% of publications, followed by the 2010s and 1980s with 13.64% and 9.10% of publications, respectively. The 2020s, which are still in their early stages at the time of this survey, showed only 4.5% (**Figure 2A**). It should be noted that the initial years of this decade were marked by the COVID-19 pandemic, which impacted all areas, including research. English was the predominant language in the analyzed articles, comprising 100% of the publications.

Among the analyzed articles, it was found that 36.35% (8) of the works originated from Japan (**Figure 2B**). This result may be related to the fact that *C. sinensis* is considered a typical beverage of the Asian region and is traditionally consumed in Japan[11]. The tradition and popularity of tea in the country may have stimulated greater interest and investment in research related to the plant, its properties, and health applications.

The United Kingdom accounted for 13.62% (3), followed by South Korea and Japan in collaboration with China, each totaling 9.09% (2) of the analyzed studies (**Figure 2B**). It is worth noting that all research related to China involved collaboration with Japan. This is likely due to their geographical proximity, as well as similar customs and traditions, resulting in greater interest in *C. sinensis* studies.

When dividing these data by continent, it is possible to observe that Asia concentrated the

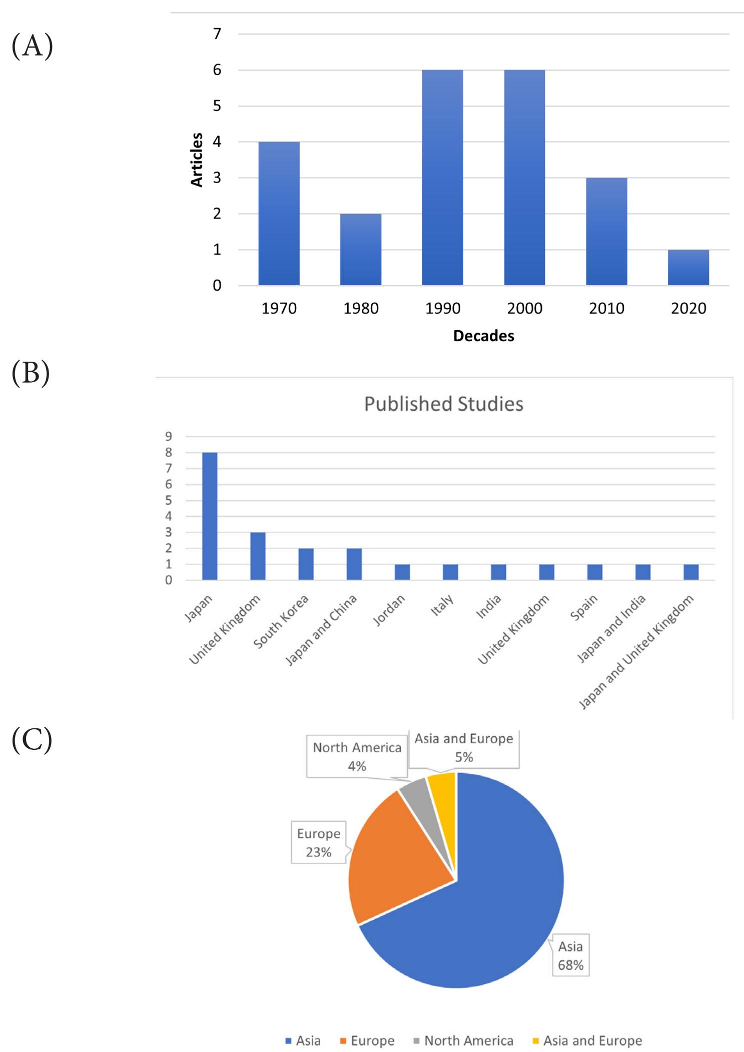


Figure 2: Scientific Publication Trends about *C. sinensis*. Total number of articles published between the 1970s and 2020s by decade (A); distribution of articles by country of origin (B); and distribution of articles by continent of origin (C).

largest number of studies with a total of 68.18% (15), followed by Europe with 22.72% (5) of studies (**Figure 2C**). Studies from Asian and European continents, either together or separately, totaled 95.45% of publications. This significant result contrasts with only 4.55% from North America, which may be related to cultural factors regarding the use of natural products, as well as financial issues. The economic crisis that began in 2008 in the United States led to cuts in federal research and development (R&D) funding, impacting scientific production[12].

Regarding the phytochemical study itself, the parts of the species studied in the analyzed works included leaves, roots, calluses, seeds, branches, trunk, and cotyledon. Leaves were the main part of *C. sinensis* studied, representing 68.18% (15) of the total studies (**Table 1 and Figure 3**). The prevalence of leaf use in many studies can be primarily attributed to their application in tea production. Indeed, leaves are one of the most commonly used parts of the plant in this process, and tea represents the most consumed form of *C. sinensis*. This trend highlights the significant cultural and economic relevance of tea in various communities worldwide[8].

Roots and seeds each accounted for 9.09% (2) of the studies. The least explored parts were the callus combined with the root, the callus combined with the branch, and a combination of parts including young leaves, developing leaves, trunk, main and lateral root, totaling 13.62% (3) together and 4.54% (1) individually (**Table 1 and Figure 3**).

Of the 22 included studies, it is important to mention that two involved cultured cells of *C. sinensis* using different parts of the plant: calluses and roots; branches and calluses, respectively. In these studies, methylxanthines, phytosterols, and terpenoids were identified. The use of calluses observed in two studies[13, 14] may be explained by the capacity of cells in this region of the plant to produce a distinct set of substances, given that these cells represent a potentially transitional physiological stage in plant development[15].

Plant cell cultures offer several advantages compared to studies in whole plants, including: rapid material generation, uniform cell development, absence of microorganism interference, and a shorter vegetative cycle. Additionally, cell cultures can produce large quantities of secondary metabolites in just two weeks, which is considerably more efficient than whole plants that may take from one season to several years to accumulate the same metabolites. This rapid biosynthesis facilitates and enhances studies[16].

Regarding extraction, this study found that methanol was the most commonly used solvent as the extracting liquid, comprising 27.27% (6). Water was used in 22.73% (5) of the extractions. Hydroalcoholic extraction (1:1) was applied in 9.09%, and

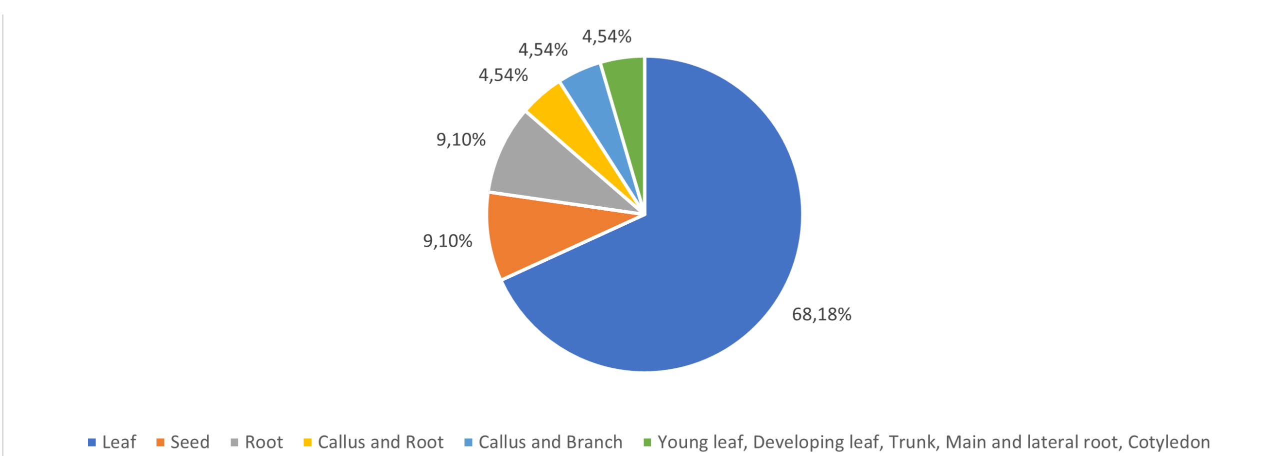


Figure 3: Parts of the C. sinensis species used in phytochemical studies

essential oil extraction represented 9.09% of the total, obtained through two techniques: pressing and steam distillation (**Figure 4**).

Extraction is an essential process to obtain substances of interest in various analyses and applications. The careful selection of the liquid used and the method in this extraction plays a fundamental role in obtaining precise and representative results[17]. In this sense, it is possible to observe that the most commonly used extracting liquids are highly polar (59.09%), aimed at obtaining more polar substances. The use of methanol, although toxic and not reproducible in therapeutic practice, represents a solvent easily removed after the extraction process of medium and high polarity substances due to its low boiling point compared to ethanol and is also widely used in phytochemical isolation and identification techniques, especially High-Performance Liquid Chromatography (HPLC). Water and hydroalcoholic mixtures, on the other hand, besides more faithfully reproducing the extraction method used by the population, are solvents used in pharmaceutical formulations for human consumption.

The substances present in *C. sinensis* were mostly isolated using chromatographic methods. High-Performance Liquid Chromatography (HPLC) was highlighted, mentioned in 60% (12) of the articles, used alone or in combination with another method. This predominance is probably due to HPLC being an advanced chromatographic technique known for using supports with extremely small particles that provide high efficiency in the separation of ions and macromolecules.

Over the past 40 years, HPLC has stood out as the main analytical technique in chemical and pharmaceutical analysis laboratories. This advancement was driven by the continuous development of new stationary phase particles, resulting in more selective, efficient, and robust columns both chemically and mechanically[18].

Thin-Layer Chromatography (TLC) was mentioned in 25% (5) of the articles, used as the sole method in these studies. Column Chromatography (CC) was mentioned in 10% (2) of the articles, used in combination in the studies. Other methods employed included: High-Performance Counter-Current Chromatography (HPCCC), ideal for separating highly polar substances without material loss; Paper Chromatography (PC); Medium Pressure Liquid Chromatography (MPLC); Silica gel ODS, Acid hydrolysis, and Enzymatic hydrolysis. Among the analyzed studies, two did not provide information about the constituent isolation method.

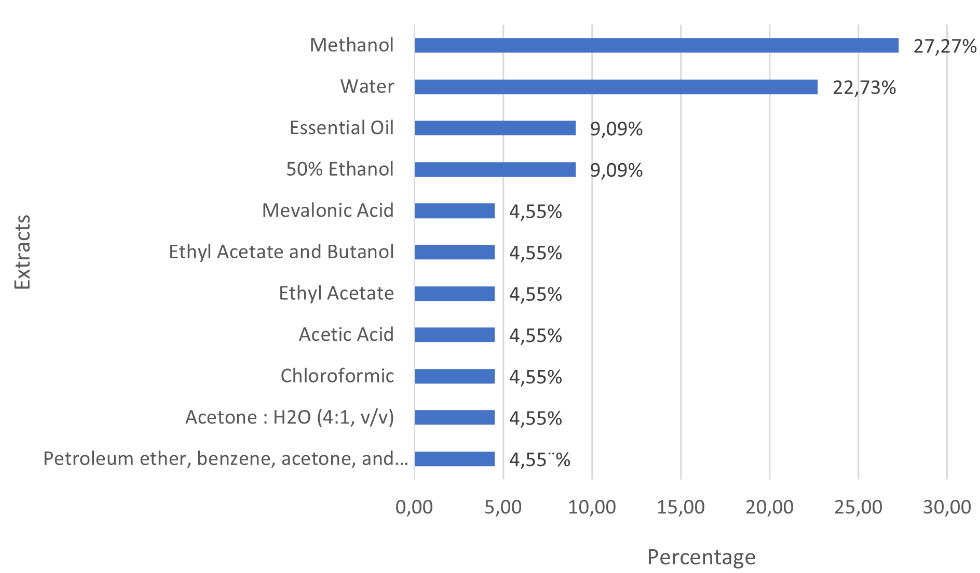
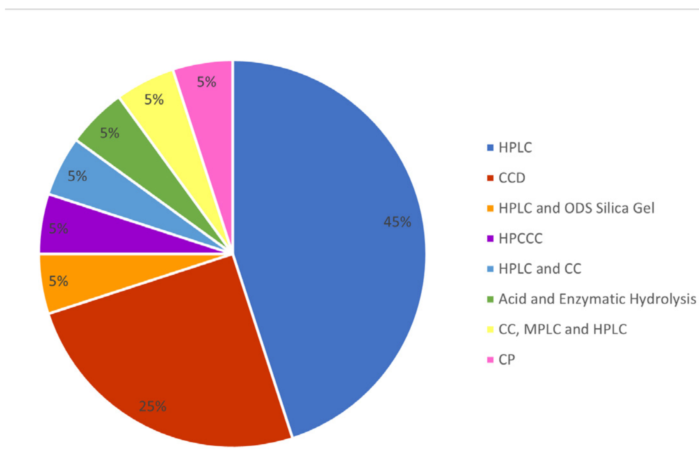


Figure 4: Extracts/solvents used in phytochemical studies of *C. sinensis*

After isolation or purification, the phytochemical study proceeds with the identification stage. The main methods used in the evaluated studies were Nuclear Magnetic Resonance (NMR), mentioned in 50% (11) of the studies, and Mass Spectrometry (MS), mentioned in 36.36% (8) of the studies (**Figure 5B**).

Identification of substances generally involves comparing their behavior in a specific system with known data in databases. Integration of methods is crucial as each offers different perspectives[19]. For example, NMR details the connectivity of atoms while MS confirms the molecular mass. By combining these data, it is possible to obtain a complete view of the structure. Different methods can also be more sensitive to specific types of substances, using multiple techniques is essential to validate results and avoid ambiguities. Therefore, combining methods is widely used for precise identification of the structure of chemical substances[20].

(A)



(B)

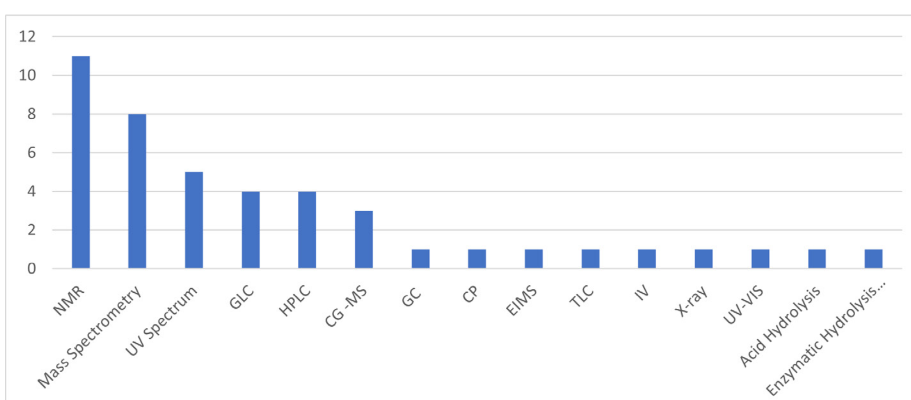


Figure 5: Number of studies citing strategies for Isolation and Identification of Chemical Constituents in *Camellia sinensis*. Methods used in the isolation of chemical constituents (A) and Methods used in the identification of chemical constituents (B). Legend: HPLC (High-Performance Liquid Chromatography) TLC (Thin-Layer Chromatography) HPCCC (High-Performance Counter-Current Chromatography) CC (Column Chromatography) MPLC (Medium Pressure Liquid Chromatography) PC (Paper Chromatography) NMR (Nuclear Magnetic Resonance) GLC (Gas-Liquid Chromatography) HPLC (High-Performance Liquid Chromatography) GC-MS (Gas Chromatography coupled with Mass Spectrometry) GC (Gas Chromatography) EIMS (Electron Impact Mass Spectrometry) TLC (Thin-Layer Chromatography) IR (Infrared) UV-Vis (Ultraviolet-Visible Spectroscopy)

Other methods included UV Spectroscopy, High-Performance Liquid Chromatography (HPLC), Column Liquid Chromatography (GLC), Gas Chromatography (GC), Gas Chromatography coupled with Mass Spectrometry (GC-MS), Ultraviolet-Visible Spectroscopy (UV-Vis), Thin-Layer Chromatography (TLC), X-Ray, Acid Hydrolysis, Enzymatic Hydrolysis, Electron Impact Mass Spectrometry (EIMS), Paper Chromatography (PC), and Infrared (IR) (**Figure 5B**).

Regarding the substances identified in the *C. sinensis* species, this study revealed the occurrence of 107 different substances, with the majority (47.68%) belonging to the flavonoid class, especially catechins with 16.82% occurrence (**Table 1 and Figure 6A**). These substances were identified in different parts of the plant, including young and developing leaves, trunk, main and lateral roots, cotyledon, and seed. The use of highly polar extracting liquids in most studies aligns with the structures of the identified flavonoids: polyhydroxylated and glycosylated. Flavonoids

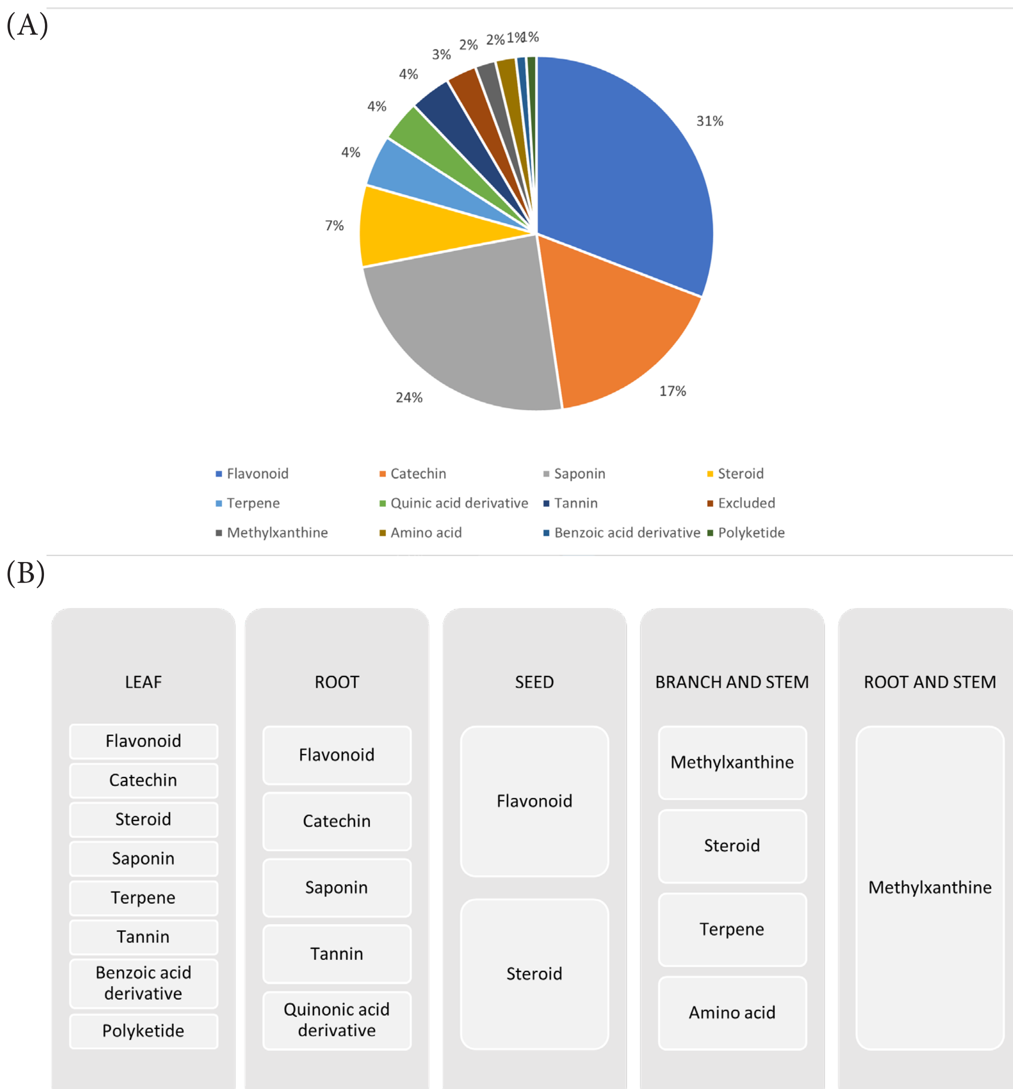


Figure 6: Profile of Substances and Secondary Metabolites in *Camellia sinensis*. Class of substances identified in the *C. sinensis* species (A); Classes of secondary metabolites identified in different parts of the plant (B).

comprise an essential and diverse class of phenolic compounds synthesized from the shikimic acid and acetic acid pathways, found abundantly and present in various parts of plants. Flavonoids exhibit a variety of biological activities, including antitumor, antioxidant, antiviral, and anti-inflammatory properties, making them of great importance in pharmacology. Interestingly, many anti-inflammatory drugs approved in recent decades were developed based on natural polyphenols, further highlighting their value in pharmaceutical research[21].

Although flavonoids are generally not considered toxic substances, there are indications that high doses could induce DNA damage, highlighting the need for deeper clinical and toxicological studies of the species to ensure its safe use[15].

In the studies by Rho et al.[2] and Lewis et al.[22], fermented leaves of *C. sinensis* were used, showing a predominance of polyphenols, especially theaflavins, and a reduction in the content of simple catechins. These data are consistent with those described by Almeida[23](2011), who states that catechins are oxidized or polymerized in the fermentation process.

According to Lamarão and Fialho[24] (2009), catechins stimulate catecholamine action and sympathetic tone, which favors a more effective distribution of abdominal fat. This underpins the use of the species as an aid in weight loss. Saponins represented 24.30% of the identified substances. These substances constitute a diverse group of chemical compounds found in a wide range of plants. Structurally, saponins are glycosides of steroids or terpenoids, presenting a hydrophilic portion and a lipophilic portion. This characteristic is responsible for reducing the surface tension of water, resulting in their detergent and emulsifying properties, allowing them to create foam when agitated in aqueous solutions[25].

Saponins emerge as another relevant class of special metabolites. Their presence in a variety of *C. sinensis* highlights their multifaceted role. This study reveals not only their frequency but also the diversity of plant parts where they are found, expanding our understanding of their distribution and relevance. With anti-inflammatory, antioxidant, and immunostimulant activities, saponins have been used throughout history in various cultures due to their medicinal properties[25]. Anti-helminthic activity, cholesterol complexation, and antiviral activity are also noted for this class of metabolites; however, many properties were verified based on in vitro assays or animal models, requiring more specific studies, including clinical trials, pharmacokinetics, and pharmacodynamics.

The survey confirmed the presence of saponins in leaves and predominantly in roots[1, 7, 26] (**Table 1**). Polar solvents were used to obtain substances from this class, which aligns with the characteristic polarity of saponins, as they are glycosides of steroids or polycyclic terpenes[27].

It is important to highlight that of the 26 saponins described in the articles that supported this survey, only one had been previously reported. Therefore, 96.15% (25) are new findings.

Steroids represented the third most abundant class of special metabolites in the species with 7.48% (**Figure 6A**). These substances are of vital importance for plants, influencing growth and resistance to stresses and pathogens[28].

In studies that identified steroids, leaves, seeds, calluses, and branches were examined, with important findings from cell cultures. Although steroids are mostly considered non-polar, some variants may contain small polar regions or functional groups, justifying the diversity of methods and solvents used in extraction[27, 28].

Other identified secondary metabolite classes included terpenes, tannins, methylxanthines, quinic acid derivatives, benzoic acid derivatives, and polyketides, in addition to two amino acids: Theanine and Glutamine[13], which are considered primary metabolites.

The survey shows that most secondary metabolites identified in *C. sinensis* have closely related biosynthesis, originating from the mixed biosynthetic route (flavonoids and condensed tannins). The survey also reveals that leaves are the part of the plant with the greatest diversity of secondary metabolites, including flavonoid, catechin, steroid, saponin, terpene, tannin, benzoic acid derivative, and polyketide.

Originating from glucose metabolism, special metabolites are biosynthesized from two main intermediates: shikimic acid and acetate[42]. Secondary metabolites, also known as special metabolites, are essential components for plant adaptation to their environment, playing a vital role in interactions with the surroundings, providing protection against predators and pathogens. Besides playing a crucial role in plant biology, many of these metabolites influence human health promotion and well-being[43].

However, in addition to the low percentage of phytochemical studies using solvents compatible with human consumption, which comprised approximately 30% of the studies, research must advance regarding toxicity and utilization forms to validate the safe use of *C. sinensis* and many other varieties of natural products in reducing body weight and preventing diet-induced obesity.

Secondary metabolites play a crucial role in plants, both in protection against predators and pathogens and in environmental adaptation. Moreover, their influence extends to human health, offering notable benefits. This study highlights the incredible diversity of metabolites present in *C. sinensis*, especially the classes of flavonoids and saponins, each contributing to different aspects of plant functionality and protection. The flavonoid class stands out as one of the most essential and diversified among phenolic metabolites. Its presence in a wide variety of plant parts, combined with its notable biological activity, confers significant importance. The frequent identification of flavonoids in this study, especially substances like catechin, epigallocatechin, epicatechin gallate, epicatechin, epigallocatechin gallate, and gallocatechin, underscores their prevalence and importance in the plant's chemical composition.

In this context, it is essential to emphasize that phytochemical studies play a crucial role in elucidating the secondary metabolites present in *C. sinensis*, identifying their structure and occurrence in different plant parts. These detailed analyses are fundamental to understanding the importance of choosing the part of the plant to be used, the method, and the liquid used in extraction, as well as knowing the classes of metabolites obtained in each situation, providing valuable information for pharmaceutical work in exploring the therapeutic potential of plants. Additionally, evaluating the toxicological risks associated with natural products is equally essential to ensure the safety and efficacy in the therapeutic and nutritional use of these compounds, protecting users' health.

Table 1 – Parts of the Species Studied and Substances Identified in *C.sinensis*

Autor	Year	Substances	Pharmacognostic Class	Part of the Plant
SHARMA[28]	1970	β-amyrin	Flavonoid	Leaf
		α-spinasterol	Steroid	
HATANAKAe HARADA[29]	1973	cis-3-Hexen-1-ol	-	Leaf
		cis-3-Hexenal	-	
		trans-2-Hexenal	-	
KHANNA et al.[30]	1974	α-espinasterol *	Steroid	Leaf
		α-spinasterol gentioside	Steroid	
		stigmasterol-7-en-3-β-ol	Steroid	
IMPERATO[31]	1976	Naringenin	Flavonoid	Leaf
		Quercetin	Flavonoid	
ITOH et al.[32]	1981	Spinasterone	Steroid	Seed
		2223-dihydrospinasterone	Steroid	
MORISHITA et al.[33]	1983	Brassinolide	Steroid	Lea
		Castasterone	Steroid	
FURUYA et al.[13]	1990	Theobromine	Methylxanthine	Branch and Callus
		Caffeine	Metilxantina	
		Theanine	Amino acid	
		Glutamine	Amino acid	
		α-spinasterol	Steroid	
		α-espinasterol β-D-glucopyranoside	Steroid	
		22-dihydro-α-espinasterol β-D-glucopyranoside	Glycosylated Steroid	
		A1-Barrigenol	Terpene	
SEKINE et al.[34]	1991	kaempferol 3-0-triglicosídeo	Flavonoid	Seed
		kaempferol 3-0-glicosídeo	Flavonoid	
GUO et al.[35]	1993	Geranil β-primeveroside	Terpene	Leaf
DAVIS et al.[36]	1997	(2R, 3R)-2-[(3aS, 3bS, 8aS) -3-[(2R, 3R) -3, 4- Di-Dihydro-3, 5, 7- trihydroxy- 2H-1-benzopyran-2- il] -3a, 6, 8, 8a- tetrahydro-5 , 7, 8a-trihydroxy-1, 6 , 8- trioxocyclopent [a] inden-3b (1H) - il] - 3, 4- di-hydro- 5, 7- di-hydroxy- 2H- 1- benzopyran- 3- il 3 , 4 , 5- trihydroxybenzoate	Polyketide	Leaf
SHERVINGTON *et al.*[14]	1998	Caffeine*	Methylxanthine	Root and Callus
		Theobromine*	Methylxanthine	

LEWIS *et al.*[22]	1998	Iso-theaflavin-3-gallate	Catechin	Leaf
		Neotheaflavin-3-gallate	Catechin	
		(2R 3R) - 2- (3 4- Dihydroxyphenyl) - 3 4- dihydro- 5 7- dihydroxy- 2H- 1- benzopyran- 3- il 1-[(2R 3R) - 3 4- dihydro- 3 5 7- trihydroxy- 2H- 1- benzopyran- 2- il] - 3 4 6- trihydroxy- 5- oxo- 5H- benzocycloheptene- 8 - carboxylate	Catechin	
LU *et al.*[26]	2000	TR Saponins A (Ácido 3-O-α-L-arabinopyranosyl (1→3)-β-D glucuronopyranosyl-21, 22-di-O-angeloyl-R-1-barrigenol-23-oic acid)	Saponin	Root
		TR Saponins B (ácido 3-O-α-L-arabinopyranosyl-(1→3)-β-D-glucuronopyranosyl-21-O-angeloyl-22-O--2-methylbutanoyl-R1-barrigenol-23-oic acid)	Saponin	
		TR Saponins C (ácido 3-O-α-L-arabinopyranosyl-(1→3)-β-D-glucuronopyranosyl-16α-O-acetyl-21-O-angeloyl-22-O-2-methylbutanoyl-R1-barrigenol-23-oic acid)	Saponin	
TERAHARA *et al.*[37]	2001	Delphinidin	Catechin	Leaf
		Cyanidin 3-O-β-d-galactosides	Catechin	
		3-O-β-d-(6-(E)-p-coumaroyl)galactopyranoside	Flavonoid	
MA *et al.*[38]	2001	(3R9R)-3- Hydroxy-78-dihydro-β-ionyl 6-O-β-D-apiofuranosyl-β-D-glucopyranoside	Terpene	Leaf
		(1R)-3-[(4R)-4-Hydroxy-2,6,6-trimetyl-1-cyclohexen-1-yl]-1-methylpropyl 6-O-D-apio-β-D-furanosyl-β--D -glucopyranoside	Terpene	
HASLAM[39]	2003	Tearubigins	Catechin	Leaf
HERNÁNDEZ *et al.*[6]	2006	Epicatechin	Catechin	Leaf
		Epigallocatechin gallate	Catechin	
		Epicatechin quinone	Catechin	
		Epigallocatechin gallate quinone	Catechin	
		Proanthocyanidin A	Catechin	
KOBAYASHI *et al.*[7]	2006	Isoteasaponin B1 (3β,16α,21β,22α)-28-(Acetyloxy)-1622-dihydroxy-21-[[(2E)-1-oxo-3-phenyl-2-propen-1-yl]oxy]olean- 12-en-3-yl O-β-D-xylopyranosyl-(1→2)-O-α-L-arabinopyranosyl-(1→3)-O-[β-D-galactopyranosyl-(1→2)] - β-D-glucopyranosiduronic acid	Triterpene Saponin	Leaf
		Isoteasaponin B2 (3β,16α,21β,22α)-21-(Acetyloxy)-1628-dihydroxy-22-[[(2E)-1-oxo-3-phenyl-2-propen-1-yl]oxy]olean- 12-en-3-yl O-β-D-xylopyranosyl-(1→2)-O-α-L-arabinopyranosyl-(1→3)-O-[β-D-galactopyranosyl-(1→2)] - β-D-glucopyranosiduronic acid	Triterpene Saponin	
		Isoteasaponin B3 (3β,16α,21β,22α)-1628-Dihydroxy-21-[[(2Z)-2-methyl-1-oxo-2-buten-1-yl]oxy]-22-[[(2E)-1-oxo-3-phenyl-2-propen-1-yl]oxy]olean-12-en-3-yl O-β-D-xylopyranosyl-(1→2)-O-α-L-arabinopyranosyl-Acid (1→3)-O-[β-D-galactopyranosyl-(1→2)]-β-D-glucopyranosiduronic acid	Triterpene Saponin	
ASHIHARA *et al.*[40]	2010	Epicatechin*	Catechin	Young leaf, developing leaf, trunk, main and lateral root, cotyledon
		Epicatechin gallate	Catechin	
		Gallocatechin	Catechin	
		Epigallocatechin gallate*	Catechin	
		Procyanidin B2 dimer	Condensed tannin	

		Procyanidin B4 dimer	Condensed tannin	
		Procyanidin C1 trimer	Condensed tannin	
		4-Galloylquinic acid	Quinic acid derivative	
		5-Galloylquinic acid	Quinic acid derivative	
		Caffeoylquinic acid	Quinic acid derivative	
		Coumaroylquinic acid	Quinic acid derivative	
		Kaempferol-O-galactosyl-O-rutinoside	Flavonoid	
		Kaempferol-O-glucosyl-O-rutinoside	Flavonoid	
		Kaempferol-3-O-glucoside	Flavonoid	
LI *et al.*[41]	2010	Epigallocatechin gallate*	Catechin	Leaf
		Epicatechin gallate*	Catechin	
		Epicatechin*	Catechin	
		Epigallocatechin	Catechin	
		Gallic acid	Benzoic acid derivative	
		Estrictinina	Tanino hidrolisável	
		Strictinin	Hydrolyzable tannin	
RHO *et al.*[2]	2019	Epigallocatechin gallate*	Catechin	Leaf
		Epicatechin gallate*	Catechin	
		Gallocatechin gallate	Catechin	
		Catechin gallate	Catechin	
		Epicatechin*	Catechin	
		Gallic acid*	Benzoic acid derivative	
		Kaempferol	Flavonoid	
		Quercetin*	Flavonoid	
		Myricetin	Flavonoid	
		Rutin	Flavonoid	
		Nicotiflorin	Flavonoid	
		Isovitexin	Flavonoid	
		Vitexin	Flavonoid	

		Daidzein	Flavonoid	
		Glycitein	Flavonoid	
		Myricetin 3-O-β--D-galactopyranoside	Flavonoid	
		Myricetin 3-O-β-D-glucopyranoside	Flavonoid	
		6′′-Galloylmyricetin 3-O-β-D-glucopyranoside	Flavonoid	
		Quercetin 3-O-β-D-galactopyranoside	Flavonoid	
		Quercetin 3-O-β-D-glucopyranoside	Flavonoid	
		Myricetin 3-O-rutinoside	Flavonoid	
		6′′-Galloylmyricetin 3-O-β-D-galactopyranoside	Flavonoid	
		Tricin 7-O-β-D-glucopyranoside	Flavonoid	
		Quercetin 3-O-[β-D-glucopyranosyl-(1→4)-O-α-L-rhamnopyranosyl-(1→ 6)-O-β-D-glucopyranoside]	Flavonoid	
		Quercetin 3-O-[β-D-glucopyranosyl-(1 → 4)-O-α-L-rhamnopyranosyl-(1 → 6)-O-β-D-galactopyranoside]	Flavonoid	
		Kaempferol 3-O-[β-D-glucopyranosyl-(1 → 3)-O-α-L-rhamnopyranosyl-(1 → 6)-O-β-D-glucopyranoside]	Flavonoid	
		Kaempferol 3-O-[β-D-glucopyranosyl-(1 → 3)-O-α-L-rhamnopyranosyl-(1 → 6)-O-β-D-glucopyranoside]	Flavonoid	
		Luteolin 8-C-glucopyranoside	Flavonoid	
		Quercetin 3-O-[2-O''-(E)-p-coumaroyl][β-D-glucopyranosyl-(1 → 3)-O-α-L-rhamnopyranosyl-(1 → 6)-O-β Lado -D-glucopyranoside]	Flavonoid	
		Quercetin 3-O-[2-O''-(E)-p-rhamnopyranosyl][α-L-rhamnopyranosyl-(1 → 6)-O-β-D-glucopyranoside]	Flavonoid	
		Quercetin 3-O-[3′′-O-(E)-p-coumaroyl][β-D-glucopyranosyl-(1 → 3)-O-α-L-rhamnopyranosyl-(1 → 6)]-β-D-glucopyranoside (quamoreokchaside I)	Flavonoid	
		Quercetin 3-O-[3′′-O-(E)-p-cumaroil][α-L-rhamnopyranosyl-(1 → 6)]-β-D-glucopyranoside (quamoreok-chaside II)	Flavonoid	
		Kaempferol 3-O-[2′′-O-(E)-p-coumaroyl][β-D-glucopyranosyl-(1 → 3)-O-α-L-rhamnopyranosyl-(1 → 6)]-β- D-galactopyranoside (kamoreokchaside I)	Flavonoid	
LEE *et al.*[1]	2023	21β-O-angeloyl-22α-(2-methylbutanoloxy)-15α,16α-diacetyloxy-28-hydroxyolean-12-ene-23-al 3β-O-α--L-arabinopyranosyl-(1 → 3)-β-D -glucuronopyranoside	Saponin	Root
		21β22α-O-diangeloyl-15α-16α-diacetyloxy-28-hydroxyolean-12-ene-23-al 3β-O- α-L-arabinopyranosyl-(1 → 3)-β-D-glucuronopyranoside	Saponin	
		Methyl ester of 21β-O-angeloyl-22α-O-(2-methylbutanoloxy)-15α,16α-28-trihydroxyolean-12-ene-23-oic acid 3β-O-α-L-arabinopyranosyl-(1 → 3)β -D-glucuronopyranoside	Saponin	
		21β-O-angeloyl-16α-acetyloxy-22α-O-(2-methylbutanoloxy)-23-hydroxyolean-12-ene 3β-O-α-L-rham-nopyransyl-(1 → 3)-β-D-glucuronopyranosyl -[28β-O-α-L-arabinopyranoside]	Saponin	
		21β-O-angeloyl-16α-acetyloxy-22-O-(2-methylbutanoloxy)-28-hydroxyolean-12-ene-23-al 3β-O-α-L--rhamnopyransyl-(1 → 3)-β -D-glucuronopyranosyl-[28β-O-α-L-arabinopyranoside]	Saponin	

		Methyl ester of 21β22α-O-diangeloyl-15α,16α-28-trihydroxyolean-12-ene-23-oic acid 3β-O-β-D-xylo-pyranosyl-(1 → 2)-α-L-arabinopyranosyl- (1 → 3)-[β-D-galactopyranosyl-(1 → 2)]-β-D-glucuronopyranoside	Saponin	
		21β-O-angeloyl-22α-(2-methylbutanoloxy)-15α, 16α-28-trihydroxyolean-12-ene 23-al 3β-O-β-D-xylo-pyranosyl-(1 → 2)-α-L-arabinopyranosyl-(1 → 3)-[β-D-galactopyranosyl-(1 → 2)]-β-D-glucuronopyranoside	Saponin	
		21β-O-angeloyl-22α-(2-methylbutanoloxy)-15α, 16α-28-trihydroxyolean-12-ene-23-al 3β-O-α-L-arabinopyranosyl-(1 → 3)-β -D-glucuronopyranoside	Saponin	
		21β-O-angeloyl-22α-(2-methylbutanoloxy)-16α-acetyloxy-28-hydroxyolean-12-eno-23-al-3β-O-α-L-arabinopyranosyl-(1→3)-β-D-glucuronopyranoside	Saponin	
		22α-O-angeloyl-16α, 21β-O-diacetyloxy-2328-dihydroxyolean-12-ene 3β-O-α-L-arabinopyranosyl-(1→3)--β-D-glucuronopyranoside	Saponin	
		22α-O-angeloyl-15α,16α,21β-O-triacetyloxy-2328-dihidroxioleano-12-eno 3β-O-α-L-arabinopyranosyl--(1→3)-β-D-glucuronopyranoside	Saponin	
		21β, 22α-O-diangeloyl-2328-dihydroxyolean-12-ene 3β-O-α-L-arabinopyranosyl-(1→3)-β-D-glucuronopyranoside	Saponin	
		21β-angeloyl-22α-(2-methylbutanoloxy)-2328-dihydroxyolean-12-ene 3β-O-α-L-arabinopyranosyl-(1→3)--β-D-glucuronopyranoside	Saponin	
		21β-O-angeloyl-22α-2-methylbutanoloxy)-15α, 16α-O-diacetyloxy-2328-dihydroxyolean-12-ene3β-O-α--L-arabinopyranosyl-(1→3)-β-D-glucuronopyranoside	Saponin	
		Methyl ester of 21β-O-angeloyl-22α-O-(2-methylbutanoloxy)-16α-acetyloxy-28-hydroxyolean-12-ene--23-oic acid -3β-O-α-L-arabinopyranosyl-(1→3)-β-D-glucuronopyranoside	Saponin	
		21β, 22α-O-diangeloyl-15α, 16α-28-trihydroxyolean-12-ene-23-al-3β-O-D-galactopyranosyl-(1→2)-[β-D--xylopyranosyl-(1→2)-β-D-galactopyranosyl-(1→3)]-β-D-glucuronopyranoside	Saponin	
		21β-O-angeloyl-22α-O-(2-methylbutanoloxy)-15α, 16α-28-trihydroxyolean-12-ene-23-al-3β-O-D-galactopyranosyl-(1→2)[-β-D-xilopiranosil-(1→2)-β-D-galactopyranosyl-(1→3)]-β-D- glucuronopyranoside	Saponin	
		22α-O-angeloyl-15α,16α,28-trihydroxyolean-12-ene-23-methyl-3β-O-D-xylopyranosyl-(1→2)-α-L-arabinopyranosyl-(1→3)-[β-D-galactopyranosyl-(1→2)]-β-D-glucuronopyranoside	Saponin	
		22α-O-angeloyl-16α,28-dihydroxyolean-12-ene-23-methyl-3β-O-D-xylopyranosyl-(1→2)-α-L-arabinopyranosyl-(1→3)-[β-D-galactopyranosyl-(1→2)]-β-D-glucuronopyranoside	Saponin	

(*) Substances previously mentioned in another study from the current survey.

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