BOLETIN LATINOAMERICANO Y DEL CARIBE DE PLANTAS MEDICINALES Y AROMÁTICAS
© / ISSN 0717 7917 / www.blacpma.ms-editions.cl

Articulo Original / Original Article

Characterization of drupe essential oil of *Schinus molle* L. from Córdoba: Potential uses

[Caracterización del aceite esencial de drupa de *Schinus molle* L. de Córdoba: Usos potenciales]

Mariela B. Maldonado[1,2], Gastón A. Gusmerini[3], Diana Labuckas[4], Carla R. Saragoza[1], Leonel Lisanti[1], Adrián Boscariol[1], Lucia Vázquez Bada[1], Ariel Márquez[1], Walter Piran[1], Florencia Lardone[1], Mariano Aguilar[5], María Teresa Gutiérrez[5] & Víctor M. Mercaú[1]

[1]Universidad Tecnológica Nacional, Facultad Regional Mendoza, Mendoza, Argentina
[2]Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina
[3]Investigador independiente, Córdoba, Argentina
[4]Instituto Multidisciplinario de Biología Vegetal, Universidad Nacional de Córdoba e Instituto de Ciencia y Tecnología de los Alimentos, Córdoba, Argentina
[5]Facultad de Ciencia Agrarias, Universidad Nacional de Cuyo, Mendoza, Argentina

Reviewed by:
Jorge Pino
Food Industry Research Institute
Cuba

Maite Rodriguez-Diaz
Universidad Andres Bello
Chile

Correspondence:
Mariela B. MALDONADO:
marielabeatriz1972@yahoo.com.ar

Section Essential Oils

Received: 27 September 2023
Accepted: 14 January 2024
Accepted corrected: 28 January 2024
Published: 30 September 2024

Citation:
Maldonado MB, Gusmerini GA, Labuckas D, Saragoza CR, Lisanti L, Boscariol A, Vázquez Bada L, Márquez A, Piran W, Lardone F, Aguilar M, Gutiérrez MT, Mercaú VM. Characterization of drupe essential oil of *Schinus molle* L. from Córdoba: Potential uses**Bol Latinoam Caribe Plant Med Aromat**
23 (5): 771 - 782 (2024)
https://doi.org/10.37360/blacpma.24.23.5.49

Abstract: The main components of the essential oil (EO) of *Schihus molle* L were characterized by Gas Chromatography with Mass Spectrometry (GC-MS). The following components found were: α-pinene (22%), limonene (19%), caryophyllene (11%), β-pinene (8%), γ-gurjunene (6%), 7- Tetracyclo [6.2.1.0(3.8)0(3.9)] undecanol, 4,4,11,11-tetramethyl (5%), β-cadinene (4.11%), ledene oxide (4%), isoledene and β -elemene (3%), and finally δ-cadinene with 2% and others. They are terpene-type compounds in different concentrations. Their potential use in medicine stands out for being anti-inflammatory, anxiolytic, antidepressant, memory loss recovery, kidney and liver problem preventions, antioxidant, immunoprotective and it is also used as anticancer, antimetastatic, among other uses. It also has a potential use as an antifungal, antimicrobial and insecticidal effect. They made it suitable for medical therapies as well as controlling of pests and microorganisms and other applications.

Keywords: *Schinus molle* L; Essential oil; Terpenes; Potential use; Medicinal use

Resumen: Los principales componentes del aceite esencial (AE) de *Schihus molle* L fueron caracterizados mediante Cromatografía de Gases con Espectrometría de Masas (GC-MS). Los siguientes componentes encontrados fueron: α-pineno (22%), limoneno (19%), cariofileno (11%), β-pineno (8%), γ-gurjuneno (6%), 7-tetraciclo [6.2.1.0(3.8)0(3.9)]undecanol, 4,4,11,11-tetrametilo (5%), β-cadineno (4,11%), óxido de ledeno (4%), isoledeno y β-elemeno (3%), y finalmente δ-cadineno con 2% y otros. Son compuestos de tipo terpeno en diferentes concentraciones. Su potencial uso en medicina destaca por ser antiinflamatorio, ansiolítico, antidepresivo, recuperador de la pérdida de memoria, preventivo de problemas renales y hepáticos, antioxidante, inmunoprotector y también se utiliza como anticancerígeno, antimetastásico, entre otros usos. También tiene un uso potencial como efecto antifúngico, antimicrobiano e insecticida. Lo hicieron adecuado para terapias médicas, así como para el control de plagas y microorganismos y otras aplicaciones.

Palabras clave: *Schinus molle* L; Aceite esencial; Terpenos; Uso potencial; Uso medicinal

INTRODUCCION

Schinus molle L. belongs to the Anacardiaceae family. This tree is known as "Aguaribay", "Molle" or "False pepper tree". This specie is distributed from southern Brazil, Paraguay, Uruguay and Argentina. In Argentina, Muñoz (2000) circumscribes its habitat in central and northern Argentina, indicating the biogeographic provinces of Paranaense and Espinal. Its original area cannot be exactly defined due to its introduction into temperate and warm areas around the world where it has become naturalized.

The plant has been used in traditional medicine in the regions where it grows (Alonso, 2015). The drupes of this tree contain an essential oil with a warm and spicy flavour that is used as a spice or condiment. In Europe, it was added as an adulterant of true pepper for several years, especially in the 19^{th} century. The fruit macerated in water creates a drink similar to hot beer, which can replace vinegar. In Mexico, they prepare a drink called “capalote” from the drupes of species of the *genus Schinus* submerged for three days in “pulque” (Alonso, 2015). In Argentina, it was included in the preparation of fernet (Gusmerini, 2022) and other drinks such as gin and also as condiment for specy foods.

In this case its fruit is a small, spherical and reddish or brown drupe, with a spicy flavour (Figure No. 1)

Figure No. 1
Schinus molle **drupe (own source)**

Alonso (2015), reports that, the essential oil from its drupes contains: α-bergamontransene, bourbonene, α and δ-cadinene, α and γ-calacorene, calamenene, camphene, carvacrol, β-caryophyllene, γ copaene γ-cubebene, p-cymene, α and β-phellandrene, α and β-pinene, α-terpineol, γ-terpinene, α and γ-muurolene, etc.

Its microbicidal action stands out (Padin, 2017; Vitón Andia, 2018; Lalangui Pazmiño y Palacios Paredes, 2021, Palomeque Camacho, 2022, Cruz-Carrillo *et al*., 2022) and its fungicidal action as well have been investigated by Pérez Moreno, (2019) and Lalangui Pazmiño y Palacios Paredes, (2021), too. Likewise, plant extracts and essential oils are important natural sources of pesticides. In the case of *S molle* L, it is also effective due to its repellent and insecticidal action (Laoudi *et al*., 2023).

The drupe has been used over time as medicine and in foods seasoning as spices. Medicinal effects have been reported due to the presence of terpenes as antiviral (da Silva *et al*., 2020; Adamski & Adamska, 2021), diuretic, antiseptic, analgesic, antioxidant and anti-inflammatory (Guala *et al*., 2009; Bigliani *et al*., 2012; Alonso, 2015; Kim *et al*., 2015; Gushiken *et al*., 2022). *S molle* essential oil is recognized as a substance generally recognized as safe by the Food and Drugs Administration (*Schinus molle* - ESO, GRAS - 182.20**)**. The FDA, which regulates and approves substances such as dietary supplements, food, and North American as a dietary supplement and categorized in class 1, as a safe specie for human consumption. This substance is also referenced in the Peruvian repository of medicinal plants. They attribute not only beneficial health properties but also documenting its nutritional use as a component in beverages and others foods. The drupes, leaves and resin are widely useful for this purpose (PromPeru, 2023).

Nevertheless, it is important to characterize the essential oil of this native specie originally from Córdoba, in order to inform and analyse its properties to know its possible uses and potentialities in detail.

MATERIALS AND METHODS

Species identification

Leaves, flowers and drupes, were collected in summer time, February 2023, for their taxonomic study. The material was picked up from trees located at Kumelen School Park, located in Callejón Arias S/N Córdoba City, GPS -31.42305 - 64.117557. The botanically identified material has been deposited in the MEN Herbarium: (Mendoza Herbarium) of the College of Agriculture, Cuyo National University, Mendoza, Argentina. The specie was identified as *Schinus molle* L. Anacardiaceae, according to Muñoz *et al*. (1993), they described the leaf and drupe morphological characters as "spheroid drupes, reddish at the beginning and finally brown upon completion of maturity". For their part, Zapater *et al*. (2018), delimits and redefines the morphological characters that allow differentiation of the species, adding the character of isomorphic leaves for Muñoz (2000), also confirms that acuminate serrated leaflets are observed, and also describes drupes that turn brown at maturity.

Physical characterization of drupes

A small sample of 25 fruits was characterized from a physical point of view. It was measured: weight with an analytical scale OHAUS, and three diameters with a 1:20 mm caliber. Then, it was calculated the area, volume, apparent density and sphericity by Sneed and Folk method (1958) and Wadel method (1932).

Obtaining essential oil

A batch of 37,013 units of reddish-brown drupes, with a moisture content of 20.78% α 0.28, whose weight was one thousand ten grams, were harvested manually from eight trees located in the Kumelen School Park. Subsequently, the fruit was ground to obtain a fine powder of approximately 25 microns with colloidal millet. Forty-five ml of essential oil was obtained in 4 hours by hydrodistillation and the resulting EO was separated through a separatory funnel. After treating with anhydrous sodium sulfate and filtering, the EO was stored in the freezer at a temperature of -20 ± 2°C until chromatographic analysis.

Sample processing

The sample was diluted 1:600 with hexane PA and placed in a gas chromatograph coupled to a Mass Spectrometry (GC-MS) [Clarus 580-SQ8, Perkin Elmer serial no. 648N7021501] A column was used: DB-5 [30 m, 0.25 mm inner diameter, 0.25 µm film thickness], Agilent brand. The conditions programmed in the GCMS were: Carrier gas: Helium at a flow rate of 1 mL/min. Injector: 250ºC. Program: Initial temp 60ºC (5 min), Ramp: 5ºC/min up to 240ºC (10 min). The sample was injected in Split mode with a ratio of 1:20.

Mass conditions: m/z = 50 at m/z = 480 (scan time: 0.2 s, time between scans: 0.1 s), with a solvent delay of 5 min. The data were acquired using the Turbo program. Mass 6. 1. The separated compounds were identified by comparing the TR and the masses with those in the database.

RESULTS AND DISCUSSION

Table No. 1 shows the major measures of fruits. The drupe of *Schinus molle* L has an average mass 0.27 g α 0.01, average diameter 4.37 mm α 0.23, calculated area 60.29 mm^2 α 6.48, calculated volume 42.20 mm^3 α 7.14, sphericity 0.90 α 0.07 and apparent density 0.0006α 0.00. The sphericity calculated by Sneed and Folk (1958) and the true sphericity calculated by the Wadell method (1932), very close to 1, confirm the spheroid shape described by the first authors to identify it as Muñoz *et al*. (1993).

The compounds identified in the EO of *S. molle* L. are presented in Table No. 2. It can be seen that 26 compounds were separated, from which 11 components were identified, among the majority (51%) are α pinene, limonene and caryophyllene (21.88%; 19.80% and 10.63%, respectively). Among the minority ones (approximately 36%) β pinene, γ-gurjunene, β-cadinene, Tetracyclo [6.2.1.0(3.8)0(3.9)] undecanol, 4,4,11,11-tetramethyl, ledene, isoledene. 15 could not be identified (and presented areas less than 2%). The detail of the chromatogram is presented in the supplementary material.

Sample	Diameter Axis A (mm)	Diameter Axis B (mm)	Diameter Axis C (mm)	Mass (g)	Calculated Area (mm^2)	Calculated Volume (mm^3)	Sphericity (By Sneed & Folk)	Sphericity (By Wadell)	Apparent density
1	4.670	4.210	4.100	0.029	58.811	42.409	0.798	1.000	0.001
2	4.510	4.330	4.120	0.024	58.630	42.213	0.846	1.000	0.001
3	4.480	4.200	4.050	0.022	56.567	40.006	0.835	1.000	0.001
4	4.930	4.630	4.610	0.034	70.089	55.175	0.893	1.000	0.001
5	4.760	4.740	4.280	0.028	66.284	50.744	0.810	1.000	0.001
6	4.800	4.020	3.920	0.025	56.656	40.100	0.708	1.000	0.001
7	4.290	3.860	4.210	0.026	53.327	36.618	0.998	1.000	0.001
8	4.690	4.300	4.290	0.034	61.561	45.418	0.861	1.000	0.001
9	4.910	4.800	4.500	0.028	70.485	55.644	0.846	1.000	0.001
10	4.270	4.140	4.100	0.029	54.629	37.967	0.932	1.000	0.001
11	4.630	4.510	4.470	0.026	64.658	48.889	0.940	1.000	0.001
12	4.920	4.590	4.510	0.028	68.613	53.442	0.860	1.000	0.001
13	4.640	4.510	4.240	0.028	62.585	46.556	0.843	1.000	0.001
14	4.690	4.640	4.360	0.031	65.421	49.756	0.867	1.000	0.001
15	4.823	4.780	4.360	0.030	68.056	52.792	0.820	1.000	0.001
16	4.510	4.320	4.110	0.035	58.449	42.018	0.842	1.000	0.001
17	4.450	3.940	4.360	0.012	56.745	40.194	1.000	1.000	0.000
18	5.080	4.680	4.620	0.032	72.181	57.665	0.850	1.000	0.001
19	4.610	4.360	4.330	0.023	61.746	45.624	0.899	1.000	0.000
20	4.670	4.130	3.960	0.031	56.834	40.289	0.749	1.000	0.001
21	4.410	4.160	4.020	0.023	55.330	38.700	0.847	1.000	0.001
22	4.260	4.080	3.970	0.029	52.896	36.175	0.881	1.000	0.001
23	4.330	4.100	3.950	0.021	53.499	36.796	0.847	1.000	0.001
24	4.370	4.160	4.100	0.025	55.682	39.070	0.895	1.000	0.001
25	4.080	3.830	3.770	0.031	47.620	30.900	0.872	1.000	0.001
Average ± Desvest	**4.59±0.25**	**4.24±0.27**	**4.29±0.27**	**0.027±0.01**	**60.29±6.48**	**44.20±7.14**	**0.89±0.07**	**1.00±0.00**	**0.0006±0.00**

Table No. 1
Physical characteristics of the *Schinus Molle* L drupe

N º	TR	Area %	Identification
1	6.904	21.88	α-pinene
2	8.215	0.31	
3	8.315	8.09	β-pinene
4	8.82	1.11	
5	9.925	0.74	
6	10.095	19.80	Limonene
7	13.662	0.51	
8	13.847	0.25	
9	15.408	0.59	
10	19.544	1.27	

11	20.6	0.68	
12	21.01	2.81	β-elemene
13	21.75	10.63	Caryophyllene
14	21.985	0.51	
15	22.25	1.38	
16	22.606	1.15	
17	22.801	1.26	
18	23.171	1.07	
19	23.296	4.11	β-cadinene
20	23.686	6.39	γ-gurjunene
21	24.091	2.02	δ-cadinene
22	24.301	1.85	
23	25.612	4.80	7-Tetracyclo [6.2.1.0(3.8)0(3.9)] undecanol, 4,4,11,11- tetramethyl-
24	25.747	3.82	ledene oxide
25	26.477	0.35	
26	27.047	2.62	Isoledene

Table No. 2
Chemical composition of *Schinus Molle* L essential oil

Among the terpenes in the *S. molle* L essential oil, classified according to isoprene units (C5), we can mention monoterpenes (C10) among them, the compounds identified as α-pinene, β-pinene, limonene and 7-Tetracyclo [6.2.1.0(3.8)0(3.9)] undecanol, 4,4,11,11-tetramethyl] and among the sesquiterpenes (C15) the compounds identified as β-elemene, caryophyllene, β-cadinene, γ-gurjunene, δ-cadinene, ledene oxide and isoledene.

In the study conducted by Giuffrida *et al*. (2020), 51 components were identified in the essential oil (EO) of *S. molle* L fruits collected in Montevideo province, Uruguay. These components represented 77.41% hydrocarbon monoterpenes, 10.83% hydrocarbon sesquiterpenes, and 2.81% oxygenated sesquiterpenes. The fruit essential oil was characterized mostly by the presence of Limonene (16.98%), β-caryophyllene (2.45%), β-pinene (1.32%), α-pinene (1.21%), and caryophyllene oxide (0.67%).

On the other hand, in the research conducted by Volpini-Klein *et al*. (2021), had numerous components identified in the essential oil derived from fruits collected in Naviraí-MS, Brazil. These fruits were harvested in December (summer) at a mature state (5 kg). The essential oil is characterized by its 24 components, among the main, including α-pinene: 0.5%, β-pinene: 0,5%, β-elemene: 1%, Caryophyllene oxide: 1.6%, ∂-cadinene: 1.2%. These components represent 65.6% hydrocarbon monoterpenes, 23.9% hydrocarbon sesquiterpenes, and 3.6% oxygenated sesquiterpenes.

α and β-pinene

As it can be seen in Table No. 2 and Figure No. 2, pinene (C10) is a bicyclic monoterpene. This terpene is also present in cannabis oil (Weston-Green *et al*., 2021). It has a piney smell that is reminiscence of the fresh scent of a forest. α -pinene is also abundant in softwood oils. Rosemary is another familiar source of α-pinene (Shahina *et al*., 2022), as eucalyptus oil (Almas *et al*., 2021) and orange peel oil and other fruits (Golmohammadi *et al*., 2018, Karthikeyan *et al*., 2022).

In this work, α-pinene was found at 21.88% and β-pinene at 8.09%, unlike the characterization made by Bigliani *et al*. (2012), found 13.80% α-pinene and 5.8% β-pinene. In contrast Volpini-Klein (2021) found 0,5% of α and β-pinene, and Giuffrida *et al*. (2020), found 1,32% of β-pinene and 1,21 of α -

pinene. Other authors such as Kratz *et al*. (2018), found that the essential oil of *Schinus molle* L, extracted from berries and leaves, contained α-pinene and β-pinene like rosemary and sage essential oil and ρ-cymene like oregano essential oil (Burt, 2004; Kasimala & Kasimala, 2012). Regarding medicinal properties, scientific information indicates that α-pinene found in the essential oil of *Schinus molle L* berries has amazing potential as an anti-inflammatory (Kim *et al*., 2015), bronchodilator (Yang *et al*., 2011), analgesic (Li *et al*., 2016), anxiety reliever (Satou *et al*., 2013), skin protector against UV rays (Karthikeyan *et al*., 2018), antimicrobial agent together with β-pinene and even as a tool to combat short-term memory impairment (Lee *et al*., 2017). This terpene is so potent that it is also used in medicine to treat kidney and liver problems (Sybilska *et al*., 1994).

Limonene

As it is illustrated in Table No. 2 and Figure No. 2, Limonene (C10) has a chiral carbon as stereocenter. Thus, there are two optical isomers: R-limonene and S-limonene (formerly dextro and levo, respectively), the latter also known as L-limonene. The composition of essential oil presented a limonene percentage of 19.80% compared to the reported by Bigliani *et al*. (2012), who found 12.81%. In comparison the essential oil analysed by Giuffrida *et al*. (2020), discovered 16.98% that was absent in the analysis reported by Volpini-Klein *et al*. (2021). Limonene has chemopreventive and chemotherapeutic properties for breast, skin, lung and stomach cancer (Chao *et al*., 2017) It was found that limonene could inhibit spared nerve injury (SNI)-induced mechanical hyperalgesia in mices receiving intrathecal injection of glycoprotein (gp120); limonene has the ability to mitigate migraine by diminishing the hyperalgesia associated with it (Eddin *et al*., 2021).

Caryophyllene or β-Caryophyllene

As it is shown in Table No. 2 and Figure No. 2, the Caryophyllene (C15) or β-Caryophyllene present in the Aguaribay OE reached a concentration of 10.63%, similar to the 11.88% of the characterization of Bigliani *et al*. (2012). This concentration was higher than those reported by Giuffrida *et al*. (2020), who found β-caryophyllene (2.45%) in the essential oil and Volpini-Klein *et al*. 2021, found 3,2% of Z-Caryophyllene. This is an organic compound classified primarily as a natural occurring bicyclic sesquiterpene notable for having a cyclobutane ring. This terpene is one of the main components of the essential oils of many cannabis plants (Kratz *et al*., 2018). In addition, it was tested with excellent results in attenuating cognitive impairment induced by exposure to aspartame, a well-known food additive (Rosa *et al*., 2023). At the therapeutic level, caryophyllene stimulates the body's CB2 receptors, which have been linked to the regulation of dopamine secretion, so they are closely related to addiction management (Gertsch *et al*., 2008). In addition, it has properties to be an antidepressant (Bahi *et al*., 2014), and to be used for the prevention and treatment of osteoporosis (Yamaguchi & Levy, 2016). It has a strong local anesthetic action that seems to be strictly dependent on its chemical structure (Ghelardini *et al*., 2001). Both β-caryophyllene and β-caryophyllene oxide can be used for treatments against different types of cancer and chronic pain (Fidyt *et al*., 2016). It was used in the treatment of wounds in rats, giving excellent results due to its antioxidant properties and re-epithelialization (Gushiken *et al*., 2022). Its antimicrobial property against periodontopathogens can also be added (Yoo & Jwa, 2019). This substance is also is useful for diabetes treatments having a promising potential for insulin secretion and sensitivity (De Fronzo *et al*., 2015). It has been shown to have pharmacological effect against ischemic stroke (Hu *et al*., 2022). It also acts as a therapeutic agent against the damage produced by MPP+ treatment in Parkinson's Disease (Wang *et al*., 2018).

Elemene

As it can be seen in Table No. 2 and Figure No. 2, Elemene (C 20), is a compound also found at 2.81% in the essential oil studied. This was higher than the values:0.39%, reported by Bigliani *et al*. (2012), and higher than 1.0% and 1.5% also by Volpini-Klein *et al*. (2021), for the same specie. The same compound was absent in the essential oil analysed by Giuffrida *et al*. (2021). This substance contains three unsaturated double bonds, which are classified as α-elemene, β-elemene and δ-elemene depending on the position of the double bond. Among them, β-elemene has the highest antitumor activity. The chemical name of β-elemene is 1-methyl-1-vinyl-2,4-diisopropenyl-cyclohexane, the molecular formula is $C_{15}H_{24}$. β-elemene has also been extracted from the medicinal herb *Turmeric wenyujin*, where it has been found to have a broad spectrum of antitumor activity, high efficacy and low toxicity, and can cross the blood-brain barrier. Compared with traditional chemotherapy drugs, in addition to its antitumor effect, it can also have an immunoprotective effect (Zhang *et al*., 2021). β-elemene has sensitization properties, and anti-inflammatory and antioxidant effects. It has been broadly used to treat different types cancers due to its excellent anti-tumor activity, inhibition of tumor cell migration, and relatively minor adverse effects (Chen *et al*., 2023).

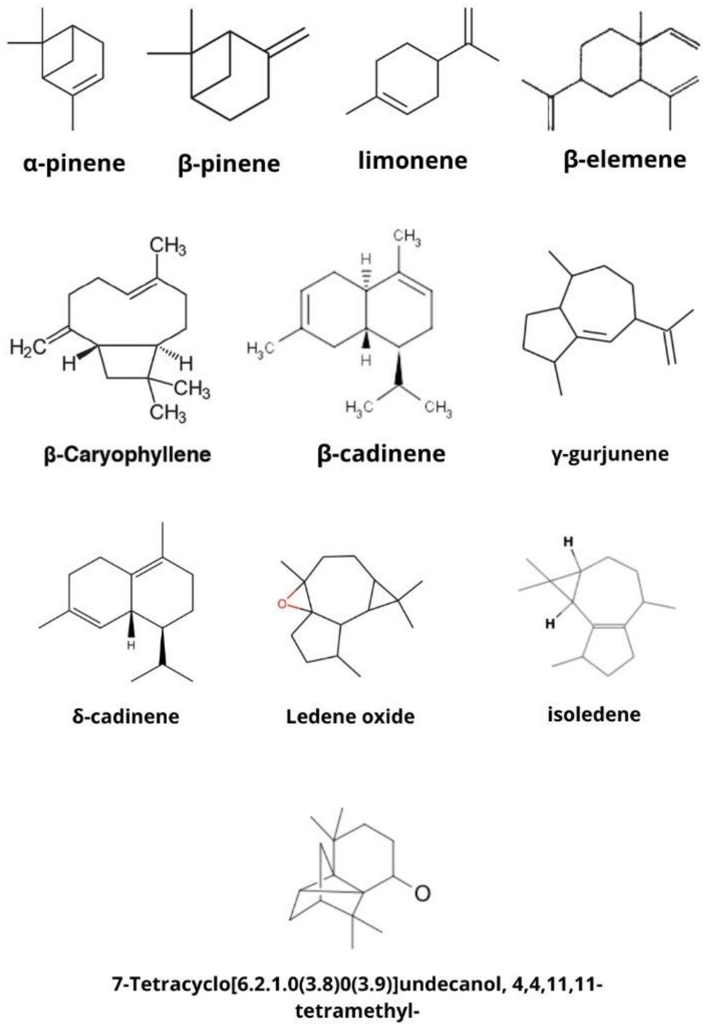

Figure No. 2
Chemical structures identified through the GC-MS

Isoledene
As it is evidenced in Table No. 2 and Figure No. 2, Isoledene (C15) is a sesquiterpene and is present in the essential oil of *S molle* L. at 2.6%, but was not found by Bigliani *et al*. (2012), neither by Giuffrida *et al*. (2020), and by Volpini-Klein *et al*. (2021), possibly due to the variabilities of the agronomic and physiological contexts in which the plants grow. It is a sesquiterpene (C15) whose activity has been studied in the medicinal sector, inducing selective cytotoxic effects towards human colorectal carcinoma cell lines, in addition to inducing typical apoptotic changes in the morphology of colon cancer cells (Asif *et al*., 2016). In the agro-industrial sector, it is part of essential oils used as biodegradable plant pesticides against the *Drosophila melanogaster*

(Valdez *et al*., 2018).

Ledene oxide

As it is shown in Table No. 2 and Figure No. 2 the molecule of Ledene-(I) oxide (H_{24} $C_{15}O$), is a sesquiterpene (C15) that contains oxygen. It was found in 3.82% from the essential oil of *S molle* L, and it was not reported by others authors as Bigliani *et al*. (2012), Giuffrida *et al*. (2020), and Volpini-Klein *et al*. (2021). In the medicinal field, an essential oil from the *Tripleurospermum conoclinium* plant was used, having ledene oxide as its main component. It was discovered that this oil has anti-diabetic activity and anti-inflammatory properties in addition to antioxidant properties (Servi *et al*., 2020). Likewise, a stereoisomer of this, from an essential oil of *Myric rubra* leaves, has antioxidant characteristics and its anticancer capacity was tested in lung cancer cells as demonstrated Yin *et al*. (2019).

β and δ-cadinene

As it is illustrated in Table No. 2 and Figure No. 2, δ-cadinene (C15) is a sesquiterpene present in the essential oil of *S molle* L at 2.02% compared to 1.53% found by Bigliani *et al*. (2012), who also found the presence of γ-cadinene at 0.22%. Giuffrida *et al*. (2020), reported 0,05% and it was absent in Volpini-Klein *et al*. (2021), research. Two mechanistic proposals have been made for the formation of δ-cadinene: a 1,10 ring-closure mechanism leading to the key intermediate germacradienyl cation, or a 1,6-ring closure leading to the alpha-bisabolyl carbocation (Loizzi, 2017). (+)-δ-cadinene synthase from *Gossypium arboreum* (cotton tree) is a sesquiterpene cyclase that catalyzes the cyclization of farnesyl diphosphate in the first step of gossypol biosynthesis. This phytoalexin defends the plant from bacterial and fungal pathogens (Gennadios *et al*., 2009). However, anticancer capacity was tested in ovarian cancer cells, inhibiting them through caspase-dependent apoptosis and cell cycle arrest (Hui *et al*., 2015).

In Table No. 2, the sesquiterpene β-cadinene, present in the essential oil of *S molle* L at 4.11%, was not reported by authors as Bigliani *et al*. (2012), Giuffrida *et al*. (2020) and Volpini-Klein *et al*. (2021). Nevertheless these last authors reported γ-cadinene in 1,2 y 3% at 120 min and 240 min respectively (Volpini-Klein *et al*., 2021) and 0,45% by Giuffrida *et al*. (2020). β-cadinene is a bicyclic sesquiterpene. Among its possible applications, it was studied as a possible treatment for bacterial and fungal infections (Shalini *et al*., 2023; Kim & Shin, 2005). Its action has been corroborated by other studies such as that of Shalini *et al*. (2023), finding it as the main compound of *Acorus calamus*.

γ-Gurjunene

As it is depicted in Table No. 2 and Figure No. 2, γ-Gurjunene (C15) was found in the EO in a 6.39% higher than that found by Bigliani *et al*. (2012), in the same type of oil, but it was absent in the Giuffrida *et al*. (2020), and Volpini-Klein *et al*. (2021), researches. γ-Gurjunene is a natural sesquiterpene isolated from gurjunene balsam. It is obtained by isomerization of α-gurjunene in an acid medium. (+)-γ-gurjunene is a sesquiterpene hydrocarbon with a guaiana skeleton (Miyazawa *et al*., 1998). It is found in *Lantana camara* and has insecticidal properties.

On the other hand, while 7-Tetracyclo [6.2.1.0(3.8)0(3.9)] undecanol, 4,4,11,11-tetramethyl- shown in Table and in Figure No. 2, was found in the distilled essential oil of *S molle* L. Bigliani *et al*. (2012), Giuffrida *et al*. (2020), and Volpini-Klein *et al*. (2021), reported other terpenes such as Tricyclene, Camphene, Sabinene, β-Myrcene, α-Phellandrene p-Cymene β-Phellandrene, α-Copaene, α-thujene; α- and γ-terpinene, mycene, terpinolene, aromadederene, α-humulene, β-selinene, β-copaene and others in few concentrations. These differences, as mentioned above, could be due to cultural, agronomic or physiological factors that respond to the need of the plant in the face of external stressors and also to the fact that the chromatographic analysis does not report those compounds whose concentration is less than 2%, because there are missing compounds in the database library to complete.

Finally, the essential oil of *S molle* L and its terpenes deserves to be studied in depth, for its added value that could convert drinks or foods into functional foods with beneficial characteristics for health. The terpene composition is important for the manufacture of artisan drinks such as beer (Valdez, 2019) or Aguaribay Fernet (Gusmerini, 2022) since they can be added in small doses to the same or to others as a potential drink with medicinal effects and functional characteristics.

Figure No. 2 shows the structures found by

GC/MS chromatography. Substances with an area less than 2% are not identified and reported by the analysis.

CONCLUSIONS

The essential oil of *Schinus molle* L, collected in the capital city of Córdoba, has mostly terpene-type compounds in different concentrations: α and β pinene, limonene and β caryophyllene, γ- gurjunene, β-cadinene, Tetracyclo [6.2.1.0(3.8)0(3.9)] undecanol, 4,4,11,11-tetramethyl-, ledene, isoledene. In addition to traditional uses (condiments, flavourings, seasonings) due to their sensory and organoleptic properties, and there are also medicinal properties attributed to the components of EO. Its potential use in medicine stands out for being anti-inflammatory, anxiolytic, antidepressant, memory loss recovery, kidney and liver problems prevention, antioxidant, immunoprotective and it is used as anticancer, antimetastatic as well among others. Besides, it has a potential antifungal, antimicrobial and insecticidal effect. It can also be incorporated into beverages or foods due to its strong medicinal effect. The substances reported in the analysis can have a beneficial effect on health when used in adequate doses. This study not only involves medicinal properties of *S molle* L but also highlights its historical and traditional importance as a spice and condiment.

In conclusion, the essential oil of *Schinus molle* L. from Córdoba emerges as a promising resource with potential applications on pharmaceutical, therapeutic, and culinary fields. β-caryophyllene, with its anti-inflammatory action, among the others, presents itself as an important component that would justifying a further research to maximize its application in the field of health and well-being.

REFERENCES

Adamski A, Adamska J. 2021. The use of essential oils - alpha and β-pinene in the treatment of Covid-19. **Anal Clin Med Case Rep** 7: 1 - 4. **https://doi.org/10.47829/ACMCR.2021.7903**

Almas I, Innocenta E., Machumia F., Kisinza W 2021. Chemical composition of essential oils from *Eucalyptus globulus* and *Eucalyptus maculata* grown in Tanzania. **Scientific African** 12: e00758. **https://doi.org/10.1016/j.sciaf.2021.e00758**

Alonso J. 2015. **Tratado de fitoquímicos y nutracéuticos.** Corpus Editorial, Rosario, Argentina.

Asif M, Shafaei A, Jafari SF, Mohamed SK, Ezzat, MO, Abdul Majid AS, Oon CE, Petersen SH, Kono K, Abdul Majid AMS. 2016. Isoledene from *Mesua ferrea* oleo-gum resin induces apoptosis in HCT 116 cells through ROS-mediated modulation of multiple proteins in the apoptotic pathways: A mechanistic study. **Toxicol Lett** 257: 84 - 96. **https://doi.org/10.1016/j.toxlet.2016.05.027**

Bahi A, Al Mansouri S, Al Memari E, Al Ameri M, Nurulain SM, Ojha S. 2014. β-Caryophyllene, a CB2 receptor agonist produces multiple behavioral changes relevant to anxiety and depression in mice. **Physiol Behav** 135: 119 - 124.

Bigliani MC, Rossetti V, Grondona E, Lo Presti S, Paglini PM, Rivero V, Zunino MP, Ponce AA. 2012. Chemical compositions and properties of *Schinus areira L*. essential oil on airway inflammation and cardiovascular system of mice and rabbits. **Food Chem Toxicol** 50: 2282 - 2288. **https://doi.org/10.1016/j.fct.2012.04.025**

Burt S. 2004. Essential oils: their antibacterial properties and potential applications in foods: A review. **Int J Food Microbiol** 94: 223 - 253. **https://doi.org/10.1016/j.ijfoodmicro.2004.03.022**

Chao Y, Hui C, Hongli C, Balian Z, Xuzhong L, Jiong C. 2017. Antioxidant and anticancer activities of essential oil from *Ganna navel* orange peel. **Molecules** 22: 1391. **https://doi.org/10.3390/molecules22081391**

Chen X, Huang C, Li K. Liu J, Zheng Y, Feng Y and Yin G. 2023. Recent advances in biosynthesis and pharmacology of β-elemene. **Phytochem Rev** 22: 169 - 186. **https://doi.org/10.1007/s11101-022-09833-0**

Cruz-Carrillo A, Rodríguez NN, Rodríguez CE. 2010. Evaluación *in vitro* del efecto antibacteriano de los extractos de *Bidens pilosa*, *Lantana camara*, *Schinus molle* y *Silybum marianum*. **Rev UDEA Actual Divulg Cient** 13: 117 - 124.

da Silva KR, Baia FPL, Byler KG, Setzer WN. 2020. Essential oils as antiviral agents, potential of essential oils to treat SARS-CoV-2 infection: An *in-silico* investigation. **Int J Mol Sci** 21: 3426.

https://doi.org/10.3390/ijms21103426

De Fronzo RA, Ferrannini E, Groop L, Henry RR, Herman WH, Holst JJ, Hu FB, Kahn CR, Raz I, Shulman GI, Simonson DC, Testa MA, Weiss R. 2015. Type 2 diabetes mellitus. **Nat Rev Dis Primers** 1: 15019. https://doi.org/10.1038/nrdp.2015.19

Eddin LB, Jha NK, Meeran MFN, Kesari KK, Beiram R, Ojha S. 2021. Neuroprotective potential of limonene and limonene containing natural products. **Molecules** 26: 4535. https://doi.org/10.3390/molecules26154535

Fidyt K, Fiedorowicz A, Strządała L, Szumny A. 2016. β-caryophyllene and β-caryophyllene oxide-natural compounds of anticancer and analgesic properties. **Cancer Med** 5: 3007 - 3017. https://doi.org/10.1002/cam4.816

Gennadios HA, Gonzalez V, Di Costanzo L, Li A, Yu F, Miller DJ, Allemann RK, Christianson DW. 2009. Crystal structure of (+)-δ-cadinene synthase from *Gossypium arboreum* and evolutionary divergence of metal binding motifs for catalysis. **Biochemistry** 48: 6175 - 6183. https://doi.org/10.1021/bi900483b

Gertsch J, Leonti M, Raduner S, Racz I, Chen JZ, Xie XQ, Altmann KH, Karsak M, Zimmer A. 2008. Beta-caryophyllene is a dietary cannabinoid. **Proc Natl Acad Sci USA** 105: 9099 - 9104. https://doi.org/10.1073/pnas.0803601105

Ghelardini C, Galeotti N, Mannelli LC, Mazzanti G, Bartolini A. 2001. Local anaesthetic activity of β-caryophyllene. **Il Farmaco** 56: 387 - 389. https://doi.org/10.1016/s0014-827x(01)01092-8

Giuffrida D, Martínez N, Arrieta-Garay Y, Fariña L, Boido E, Dellacassa E. 2020. Valorisation of *Schinus molle* fruit as a source of volatile compounds in foods as flavours and fragrances. **Food Res Int** 133: 109103. https://doi.org/10.1016/j.foodres.2020.109103

Golmohammadi M, Borghei A, Zenouzi A, Ashrafi N, Taherzadeh MJ. 2018. Optimization of essential oil extraction from orange peels using steam explosion. **Heliyon** 4: e00893. https://doi.org/10.1016/j.heliyon.2018.e00893

Guala MS, Elder HV, Perez G, Chiesa A. 2009. Evaluación del poder antioxidante de fracciones de aceite esencial crudo de *Schinus molle L*. obtenidas por destilación al vacío. **Información Tecnologica** 20: 83 - 88. https://doi.org/10.4067/S0718-07642009000200011

Gushiken LFS, Beserra FP, Hussni MF, Gonzaga MT, Ribeiro VP, de Souza PF, Campos JCL, Massaro TNC, Hussni CA, Takahira RK, Marcato PD, Bastos JK, Pellizzon CH. 2022. Beta-caryophyllene as an antioxidant, anti-inflammatory and re-epithelialization activities in a rat skin wound excision model. **Oxid Med Cell Longevity** 2022: 1 - 21. https://doi.org/10.1155/2022/9004014

Gusmerini GA. 2022. **Proyecto Fernet Aguaribay (Fernesan)**. Premio INNOVAR. Mención en Catálogo Innovar 2022. Buenos Aires, Argentina.

Hu Q, Zuo T, Deng L, Chen S, Yu W, Liu S, Liu J, Wang X, Fan X, Dong Z. 2022. β-Caryophyllene suppresses ferroptosis induced by cerebral ischemia reperfusion via activation of the NRF2/HO-1 signaling pathway in MCAO/R rats. **Phytomedicine** 102: 154112. https://doi.org/10.1016/j.phymed.2022.154112

Hui LM, Zhao GD, Zhao JJ. 2015. δ-Cadineno inhibits the growth of ovarian cancer cells via caspase-dependent apoptosis and cell cycle arrest. **Int J Clin Exp Pathol** 8: 6046 - 6056.

Karthikeyan R, Kanimozhi G, Prasad NR, Agilan B, Ganesan M, Srithar, G. 2018. Alpha pinene modulates UVA-induced oxidative stress, DNA damage and apoptosis in human skin epidermal keratinocytes. **Life Sci** 212: 150 - 158. https://doi.org/10.1016/j.lfs.2018.10.004

Karthikeyan R, Kanimozhi G, Prasad NR, Agilan B, Ganesan M, Srithar G. 2022. Extraction and purification of α-pinene; a comprehensive review. **Crit Rev Food Sci Nutr** 1 - 26. https://doi.org/10.1080/10408398.2022.2140331

Kasimala MB, Kasimala BB. 2012. A review on Brazilian pepper plant: *Schinus molle*. **J Atoms Molec** 2: 6 - 13.

Kim DS, Lee HJ, Jeon YD, Han YH, Kee JY, Kim HJ, Shin HJ, Kang J, Lee BS, Kim SH, Kim SJ, Park SH, Choi BM, Park SJ, Um JY, Hong SH. 2015. Alpha-pinene exhibits anti-inflammatory activity through the suppression of MAPKs and the NF-κB pathway in mouse peritoneal macrophages. **Am J Chin Med** 43: 731 - 742. https://doi.org/10.1142/S0192415X15500457

Kim YS, Shin DH. 2005. Volatile components and antibacterial effects of pine needle (*Pinus densiflora* S. and Z.) extracts. **Food Microbiol** 22: 37 - 45. https://doi.org/10.1016/j.fm.2004.05.002

Kratz, J, Garcia de Palau M, Peguero B. 2018. **Manual sobre cannabis medicinal**. K. Clinic First ed. Kalapa Clinic, Barcelona, España.

Lalangui Pazmiño GG, Palacios Paredes EW. 2021. Efecto inhibitorio del aceite esencial de *Schinus molle* a diferentes tiempos y concentraciones, sobre *Cándida albicans*. **Recimundo** 5: 398 - 406. **https://doi.org/10.26820/recimundo/5.(2).abril.2021.398-406**

Laoudi T, Khelfane-Goucem K, Hamani-Aoudjit S, Chebrouk F, Amrouche T, Saher L & Kellouche A. 2023. Chemical composition of essential oils from the leaves of *Schinus molle* and *Cupressus sempervirens* and their insecticidal activity against *Oryzaephilus surinamensis* (Coleoptera: Silvanidae). **J Essent Oil Bear Plants** 26: 309 - 322. **https://doi.org/10.1080/0972060X.2023.2179425**

Lee GY, Lee C, Park GH, Jang JH. 2017. Amelioration of scopolamine-induced learning and memory impairment byα-pinene in C57BL/6 mice. **Evid Based Complement Alternat Med** 4926815. **https://doi.org/10.1155/2017/4926815**

Li XJ, Yang YJ, Li YS, Zhang WK, Tang HB. 2016. α-Pinene, linalool, and 1-octanol contribute to the topical anti-inflammatory and analgesic activities of frankincense by inhibiting COX-2. **J Ethnopharmacol** 179: 22 - 26. **https://doi.org/10.1016/j.jep.2015.12.039**

Loizzi M. 2017. **Investigation of delta-cadinene synthase function with aza analogues and site-directed mutagenesis**. Doctoral Thesis, Universidad de Cardiff. Reino Unido.

Miyazawa M, Honjo Y, Kameoka H. 1998. Biotransformation of the sesquiterpenoid (+)-γ-Gurjunene using a plant pathogenic fungus, *Glomerella cingulata*, as a biocatalyst. **Phytochemistry** 49: 1283 - 1285.

Muñoz JD, Spichiger R, Ramella L. 1993. **Flora del Paraguay**. Editions des Conservatoire et Jardin botaniques de la Ville de Geneve y Missouri Botanical Garden, Suisse.

Muñoz JD. 2000. **Anacardiaceae** en: Hunziker AT. (dir.) Flora Fanerogámica Argentina. Museo Botánico, Córdoba, Argentina.

Padín EV. 2017. **Obtaining, characterization and determination of the antimicrobial activity of oleoresin from Aguaribay berries (*Schinus molle* Linn.)** Thesis, Universidad Nacional de Quilmes, Argentina.

Palomeque Camacho JD. 2022. **Efecto inhibitorio del extracto de *Schinus Molle* L. (Molle)., a diferentes tiempos y concentraciones sobre cepas de *Staphylococcus aureus*. Estudio *in vitro***. Tesis, Universidad Central del Ecuador, Quito, Ecuador.

Pérez Moreno M. 2019. **Evaluación de la capacidad antifúngica y antibacteriana de extractos de plantas invasoras (*Eucalyptus Globulus, Schinus Molle, Schinus Terebenthifolius, Zygophyllum Fabago*)**. Tesis. Universidad Miguel de Hernández de Elche, España.

Promperu. 2023. **National Technical Group Medicinal Plants. 2006**. **https://repositorio.promperu.gob.pe/items/6f6702cc-3107-461b-8ef0-0e8bce77c5b5**

Rosa EVF, Da Silveira A, Sari MHM, Sampaio TB, Dos Santos JT, Müller SG, Fighera MR Royes LFF, Nogueira CW, Oliveira MS, Furian AF. 2023. Beta-caryophyllene mitigates the cognitive impairment caused by repeated exposure to aspartame in rats: Putative role of BDNF-TrKB signaling pathway and acetylcholinesterase activity. **Behav Brain Res** 453: 114615. **https://doi.org/10.1016/j.bbr.2023.114615**

Satou T, Kasuya H, Maeda K, Koike K. 2013. Daily inhalation of α-pinene in mice: Effects on behavior and organ accumulation. **Phytother Res** 28: 1284 - 1287. **https://doi.org/10.1002/ptr.5105**

Servi H, Sen A, Dogan A. 2020. Chemical composition and biological activities of endemic *Tripleurospermum conoclinium* (Boiss. and Balansa) Hayek essential oils. **Flavour Fragrance J** 35: 713 - 721. **https://doi.org/10.1002/ffj.3610**

Shahina Z, Al Homsi R, Price JDW, Whiteway M, Sultana T, Dahms TES. 2022. Rosemary essential oil and its components 1,8-cineole and α-pinene induce ROS-dependent lethality and ROS-independent virulence inhibition in *Candida albicans.* **Plos One** 17: e0277097. **https://doi.org/10.1371/journal.pone.0277097**

Shalini K, Guleria S, Salaria D, Rolta R, Fadare OA, Mehta J, Awofisayo O, Mandyal P, Shandilya P, Kaushik N, Choi E H, Chandel SR, Kaushik NK. 2023. Antimicrobial potential of phytocompounds of *Acorus calamus*: in silico approach. **J Biomol Struct Dyn** 1 - 12. **https://doi.org/10.1080/07391102.2023.2209653**

Sneed ED, Folk RL.1958. Pebbles in the lower Colorado River, Texas, a study in particle morphogenesis. **J Geol** 66: 114 - 150. **https://doi.org/10.1086/626490**

Sybilska D, Kowalczyk J, Asztemborska M, Ochocka RJ, Lamparczyk H. 1994. Chromatographic studies of the enantiomeric composition of some therapeutic compositions applied in the treatment of liver and kidney diseases. **J Chromatogr A** 665: 67 - 73. **https://doi.org/10.1016/0021-9673(94)87033-0**

Valdez A, Delgado E, Ramírez J. 2018. Actividad adulticida y composición química del aceite esencial de hojas de *Lantana camara* sobre *Drosophila melanogaster*. **Maskana** 9: 21 - 30. **https://doi.org/10.18537/mskn.09.01.03**

Valdez LM. 2019. **Molle beer production in the Ayacucho Valley, Peru. Production and management of beverages**. Woodhead Publishing, Editor(s): Grumezescu AM, Holban AM, MacEwan University, Edmonton, Canada. **https://doi.org/10.1016/B978-0-12-815260-7.00009-2**

Vitón Andia LS. 2018. **Susceptibility of strains of *Staphylococcus aureus* and β-hemolytic *Streptococcus* to different concentrations of the ethanolic extract of the leaves of *Schinus molle* L. (molle)**. Thesis, Universidad Nacional Pedro Ruíz Gallo, Lambayeque, Peru.

Volpini-Klein AFN, Lima Junio SE, Cardoso CAJ, Cabral Marcia RP, Louro GM, Coutinho EJ, de Jesus DA, Junior DP, Simionatto E. 2021. Chemical composition of essential oils from leaves and fruits of *Schinus molle* obtained by different extraction methods (hydrodistillation, fractional hydrodistillation and steam distillation) and seasonal variations. **J Essent Oil Bear Plants** 24: 228 - 242. **https://doi.org/10.1080/0972060X.2021.1914739**

Wadell H. 1932. Volume, shape, and roundness of rock particles. **J Geol** 40: 443 - 451. **https://doi.org/10.1086/613964**

Wang G, Ma W, Du J. 2018. β-Caryophyllene (BCP) ameliorates MPP+ induced cytotoxicity. **Biomed Pharm** 103: 1086 - 1091. **https://doi.org/10.1016/j.biopha.2018.03.168**

Weston-Green K, Clunas H, Jimenez Naranjo C. 2021. A review of the potential use of pinene and linalool as terpene-based medicines for brain health: Discovering novel therapeutics in the flavours and fragrances of *Cannabis*. **Front Psychiatry** 12: 583211. **https://doi.org/10.3389/fpsyt.2021.583211**

Yamaguchi M, Levy RM. 2016. β-Caryophyllene promotes osteoblastic mineralization, and suppresses osteoclastogenesis and adipogenesis in mouse bone marrow cultures *in vitro*. **Exp Therap Med** 12: 3602 - 3606. **https://doi.org/10.3892/etm.2016.3818**

Yang Z, Wu N, Zu Y, Fu Y. 2011. Comparative anti-infectious bronchitis virus (IBV) activity of (-)-Pinene: Effect on nucleocapsid (N) protein. **Molecules** 16: 1044 - 1054. **https://doi.org/10.3390/molecules16021044**

Yin J, Li X, Huang FF, Lu MH, Yang J, Zhu LY. 2019. Chemical composition, antioxidant and anticancer activity of the essential oil from myric rubra leaves. **IOP Conf Ser: Earth Environ Sci** 346: 012085. **https://doi.org/10.1088/1755-1315/346/1/012085**

Yoo HJ, Jwa SK. 2019. Efficacy of β-caryophyllene for periodontal disease related factors. **Arch Oral Biol** 100: 113 - 118. **https://doi.org/10.1016/j.archoralbio.2019.02.015**

Zapater MA, Aquino VH, Flores CB, Lozano EC. 2018. Clarificaciones nomenclaturales y circunscripción taxonómica de *Schinus areira* (Anacardiaceae) en Argentina. **Bol Soc Arg Bot** 53: 665 - 671. **https://doi.org/10.31055/1851.2372.v53.n4.21987**

Zhang X, Chen Y, Yao J, Zhang Y, Li M, Yu B, Wang K. 2021. β-elemene combined with temozolomide in treatment of brain glioma. **Biochem Biophys Rep** 28: 101144. **https://doi.org/10.1016/j.bbrep.2021.101144**