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Biological activities of secondary metabolites of the genus *Tagetes* with emphasis on *T. erecta* (marigold)

Actividades biológicas de metabolitos secundarios del género *Tagetes* con énfasis en *T. erecta* (caléndula)

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Commercial and industrial application: Bioactive metabolites beneficial for man and the agricultural sector.

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Resumen

El género *Tagetes*, perteneciente a la familia Asteraceae cuenta con 53 especies distribuidas en el continente americano y se han registrado más de 100 metabolitos secundarios con importante actividad biológica. Dentro de este género, *Tagetes erecta*, una planta nativa de América Central es utilizada como planta ornamental y medicinal por algunos grupos endémicos. Además, es consumida como alimento en algunas regiones de México. Sin embargo, existen pocos informes sobre los compuestos y los efectos biológicos de esta especie en particular. En este artículo se resume un análisis reciente del género *Tagetes* con énfasis en *T. erecta*, centrándose en los principales metabolitos secundarios y sus propiedades biológicas atribuidas. El análisis reveló que los metabolitos con mayor presencia en especies del género *Tagetes* fueron los terpenos, tagetona, ocimeno y limoneno, además del glicósido quercetagetina y una alta presencia de compuestos fenólicos, los cuales contribuyen a potenciar sus principales actividades biológicas como compuestos antioxidantes y antinflamatorios.

Palabras clave: Compuestos bioactivos, Flor de muerto, Fitoquímica, Tagetes.

Abstract

The genus *Tagetes*, belonging to the Asteraceae family, has 53 species distributed in the American continent and more than one hundred secondary metabolites with significant biological activity have been recorded. Within this genus, *Tagetes erecta*, a native plant of Central America, is used as an ornamental and medicinal plant by some endemic groups and it is also consumed as food in some regions of Mexico. Nevertheless, there are few reports on the compounds and biological effects of this particular species. This article summarizes a recent analysis of the genus *Tagetes* with emphasis on *T. erecta* focusing on the main secondary metabolites and its attributed biological properties The analysis revealed that the metabolites with the greatest presence in species of the genus *Tagetes* were terpenes, tagetone, ocimene and limonene, in addition to the glycoside quercetagetin and a high presence of phenolic compounds, which contribute to enhance their main biological activities as antioxidant and anti-inflammatory compounds.

Keywords: Bioactive compounds, Flower of the dead, Phytochemistry, *Tagetes.*

1. Introduction

Humans have used plants to treat or cure some illness since ancient times. However, in many populations around the world, the curative properties and efficacy of medicinal plants are based on empirical knowledge which has contributed to the use of these resources without moderation and without knowing the chemical components they possess (Salehi *et al.,* 2018). Although in most major cities allopathic drugs have replaced medicinal plants, currently 80% of the world population still resorts to the use of some 28,000 plant species on the planet that have medicinal potential (Jamshidi-Kia *et al.,* 2018).

A medicinal plant is any plant species with compounds that can be used for therapeutic purposes or whose active principles can serve as precursors for the synthesis of new drugs (Süntar, 2020). These compounds tend to be mostly products of secondary metabolism, and in nature they have specific ecological functions as attractants or repellents for animals. Moreover, some of these compounds are pigments that give color to flowers responsible for the pollination process and the consequent continuity of the species (Zaynab *et al.,* 2018; Beran *et al.,* 2019).

Within the great diversity of medicinal plants that exist in the world, the genus *Tagetes*, more than 100 secondary metabolites of the genus Tagetes, belonging to the Asteraceae family have been recorded up to the previous decade (Xu *et al.,* 2012). These molecules, from secondary metabolism, have been related to the various pharmacological properties conferred on the species of this plant family, such as: gastrointestinal, antioxidant, hepatoprotective, antimicrobial, nematocidal among others. This genus consists of 53 perennial species natively distributed in the American continent (Riaz *et al.,* 2020). However, due to its few adaptation requirements, it has been able to expand in Africa, Asia and Europe continents (Xu *et al.,* 2012; Salehi *et al.,* 2018). Currently, constitute a group of plants with industrial, medical, ornamental and agricultural importance (Mupambwa *et al.,* 2017; Umar *et al.,* 2017; Giacone *et al.,* 2020; Mrnka *et al.,* 2020; Walia and Kumar, 2020). Interestingly, the most studied and representative species of this genus are *Tagetes erecta, Tagetes patula* and *Tagetes minuta*.

In Mexico, *T. erecta* is traditionally knows as “caléndula”, "cempasúchil" or "flower of the dead” (Fig. 1A). It is a plant native to Mexico and Central America, which has adapted to disturbed urban areas. This species bloom from September to December, and it is widely cultivated for ornamental purposes, especially in religious ceremonies (Fig. 1B), and as a complement to poultry feed or as a dye around the world (Rzedowski and Rzedowski, 2001).



Figure 1. *Tagetes erecta*, native species of Mexico. A) Whole plant. B) Ornamental use in religious ceremony. Source: Own photographs.

In traditional medicine, *T. erecta* is mainly used for the treatment of gastrointestinal diseases. Furthermore, in some regions of Mexico it is used as food, which enhance the importance of knowing its biological properties and its bioactive compounds (Pacheco-Pantoja *et al.*, 2021). To our knowledge, there are no reports with the compilation of information regarding the bioactive compounds and biological properties of the *T. erecta*. Therefore, the aim of this study was to develop an exhaustive and updated review of the main secondary metabolites and the biological properties contained in the species of the genus *Tagetes* with emphasis on the species *T. erecta*.

2. Secondary metabolites of biological interest of the genus *Tagetes*

2.1. Terpenes

Several researches indicate that terpenes constitute the most abundant group of secondary metabolites in essential oils of the genus *Tagetes* (Vasudevan *et al.*, 1997; Prakash *et al.*, 2012; Riaz *et al.*, 2020). These compounds originate as part of secondary plant metabolism and are also often called isoprenoids, because are made up of isoprene units. The chemical biosynthesis of terpenes can occur in two principal ways: 1) the mevalonic acid pathway and 2) the 5-phosphono-1-deoxy-D-xylulose pathway. However, the biochemical pathway used in each plant species will depend on the way in which the isoprene units are synthesized (McGarvey and Croteau, 1995).

The terpenes produced by the species of the genus *Tagetes*, possess a very important biological functions as follows: carotenoids are photosynthetic pigments, ubiquinone and plastoquinone function are an important electron transporter in vital processes such as photosynthesis. Some terpenoids have hormonal functions that regulate the growth

and development of plants and others act as structural and functional elements of the cell membrane, and some help in the protection of the plant against abiotic stress and ecological processes such as herbivory (Sandmann, 2014; Tholl, 2015).

Several studies have been in charge of characterizing the metabolites in the essential oils of leaves and flowers of species of the genus *Tagetes*, finding mainly terpenes and terpenoids. Table 1 shows several researches with an antiquity of less than 20 years, in which it is observed that the species with the most worldwide relevance for the analysis of essential oils in the genus *Tagetes* are: *T. erecta*, *T. lucida*, *T. minuta* and *T. patula*.

Table 1. Some terpenes identified in species of *Tagetes* genus during the last 20 years.

Analysed species	Part plant analysed	Method or tested extracts	Isolated terpenes/terpenoids[1]	References
T. erecta	Leaves	Hydro-distilled in a micro-Clevenger-type apparatus	(Z)-β-ocimene Dihydrotagetone (Z)-tagetone Limonene (E)-Ocimenone (Z)-Ocimenone	Singh *et al*., 2003
	Leaves, stems and flowers	Hydro-distilled in a micro-Clevenger-type apparatus	Terpinolene (E)-ocimenone (Z)-β-ocimene Piperitenone (Z)-ocimenone Limonene	Sefidkon *et al*., 2004
	Leaves and flowers	Hydro-distilled in a micro-Clevenger-type apparatus	Piperitone Piperitenone (E)-β-ocimene α-Pinene Sabinene	Ogunwande *et al*., 2006
	Flowers	Hydro-distilled in a micro-Clevenger-type apparatus	β-Cubebene Piperitone Menthone Piperitenone 1,4-Naptoquinone E-ocimene	Martínez *et al*., 2009
	Leaves	Hydro-distilled in a micro-Clevenger-type apparatus	Piperitone Piperitenone Ocimine Neophytadiene Caryophyllene	Laosinwattana *et al*., 2018
	Leaves and flowers	Aqueous and ethanolic extract	Not mentioned	Camacho-Campos *et al*., 2019
T. lucida[2]	Leaves	Hydro-distilled in a micro-Clevenger-type apparatus	(E)-β-ocimene	Regalado *et al*., 2011
T. minuta	Whole plant	Hydro-distilled	Carvone Limonene α-Pinene (Z) Ocimenone (E) Ocimenone	Scrivanti *et al*., 2003
	Whole plant	Hydro-distilled	Dihydrotagetone Cistagetone Trans-tagetone Cis-β-ocimene Limonene	Senatore *et al*., 2004

	Flowering shoots	Hydro-distilled in a micro-Clevenger-type apparatus	(Z)-β-ocimene Dihydrotagetone (E)-β-ocimene (Z)-tagetone (Z)-ocimenone (E)-ocimenone	Rajeswara-Rao *et al*., 2006
	Leaves and flowers	Hydro-distilled in a micro-Clevenger-type apparatus	Limonene Dihydrotagetone (Z)-Tagetone (E)-Ocimenone	Moghaddam *et al*., 2007
	Leaves and flowers	Steam distilled	β-ocimene Tagetone	Chamorro *et al*., 2008
	Young and senescence leaves, flowers, and fruits	Hydro-distilled in a micro-Clevenger-type apparatus	(E) Tagetone (Z) Tagetone (Z) Ocimenone (E) Ocimenone	Liza-López *et al*., 2008
	Leaves and flowers	Steam distilled	Limonene (Z)-β-Ocimene (E)-β-Ocimene p-cymene (Z)-tagetenone (E)-tagetenone α-Muurolene Verbenone	Ramaroson-Raonizafinimanana *et al*., 2009
	Flower and leaves	Hydro-distilled in a micro-Clevenger-type apparatus	Ocimene Dihydrotagetone Tagetones Ocimenones Piperitenone	Wanzala *et al*., 2013
	Flower and leaves	Hydro-distilled in a micro-Clevenger-type apparatus	Z-β-ocimene Dihydrotagetone E-ocimenone Z-tagetone	Walia *et al*., 2020
T. patula	Leaves	Hydro-distilled in a micro-Clevenger-type apparatus	Piperitone Trans-β-ocymene Terpinolene β-Caryophyllene	Rondon *et al*., 2006
	Flowers	Hydro-distilled in a micro-Clevenger-type apparatus	E-Ocimene Menthone Piperitenone Pentatriacontane	Martínez *et al*., 2009
	Whole plant	Hydro-distilled in a micro-Clevenger-type apparatus	(Z)-β-Ocimenone (E)-β-Ocimenone Terpinolene (Z) Ocimenone (E) Ocimenone δ-elemene	Prakash *et al*., 2012
	Leaves and flowers	Methanolic extract	D-Limonene Z-Ocimene Terpinolene Verbenone Piperitone	Soto-Rueda *et al*., 2018

[1]Only the major terpenes of each research are shown. Total molecules can be consulted in the reference.
[2]Most of the compounds in this species concentrated in trace amounts.

T. minuta has been the species with the most interest worldwide. The dominant terpenes in the essential oils of the leaves and the reproductive structures of this species are from the group of ocimenones and tagetones. This kind of compounds increase

in the leaves and in the reproductive structures throughout the life cycle of the plant and decrease in the senescent leaves where the major compound is an alcohol called spatulenol (Liza-López *et al.*, 2008).

Interestingly, in the case of *T. lucida*, the main component of the essential oils was not terpenes or terpenoids, is the aromatic ether called estragole. Compounds belonging to the group of terpenes concentrated in trace amounts and only (E) -β-ocimene has been quantified (Regalado *et al.*, 2011).

In the specific case of *T. erecta*, the most common terpenes found in the plants were: (Z) -β-ocimene, (E) -Ocimenone, (Z) -Ocimenone, Piperitone, Piperitenone. Interestingly, a terpene called sabinena could only be found in specimens collected in the city of Ogbomoso, belonging to southwestern Nigeria, Africa (Ogunwande and Olawore, 2006; Table 1). This data could suggest that the type and concentration of terpenes in a plant depends on the environmental conditions of the development place.

The most common terpenes found in the four species, regardless of the place of collection, or the plant part analysed, were ocimenones, piperitones, piperitinones and tagetones. The leaves and flowers of the species of the genus *Tagetes* were the most analysed plant structures, while, in more than 80% of the studies analysed, the hydro-distillation method with micro-Clevenger was the most used to obtain the essential oils (Table 1).

2.2. Alkaloids

Alkaloids have several pharmacological effects, although some they are toxic (Seneca, 2007). Some alkaloids can affect the central nervous system and the autonomic nervous system (Funayama and Cordell, 2014), and their applications can be found in different areas, mainly in industry, commerce and medicine. One of the important applications of alkaloids is the regulation of sodium channels; they can also employ as biological fertilizers and as control agents in plant protection (Plautus, 2007).

Regarding their formation process in organisms, alkaloids come from amino acid biosynthesis or the transamination process (Kishimoto *et al.*, 2016). Pyruvic acid and coenzyme-A are key compounds in the synthesis of alkaloid precursors, such as: acetyl coenzyme-A, shikimic acid, mevalonic acid and 1-deoxylxylulose-5-phosphate (Tanenbaum, 1966).

The ß-carboline japhrine and 6-ethoxy-2,4-dimethylquinoline are two examples of alkaloids present in species of the genus *Tagetes*, these molecules have been described in the petroleum ether extract of *T. patula* flowers (Xu *et al.*, 2012). Another reported alkaloid is 6-ethoxy-2,4-dimethylquinoline, present in ethanolic extract of *T. erecta* flowers (Xu *et al.*, 2012). Interestingly, the presence of the indole alkaloid is present in the essential oil of fresh leaves of *T. erecta*, a molecule that had not previously reported in this genus (Machado *et al.*, 1994).

2.3. Glycosides

Glycosides are composed of aglycone units and sugar units linked by glycosidic bonds through the action of glycosyltransferases. They are important substances in nature, due to their key role in intercellular communication and coordination of plant life. Furthermore, glycosides provide improved solubility, biological activity or stability of secondary metabolites (Feng *et al.*, 2020).

The most important glycosides are saponins, cyanogenic glycosides, cardiac glycosides, glucosinolates and flavonoid glycosides. The biochemical metabolism of glycosides is carrying by the enzyme glycosyltransferase, which transfers the active glycoside from the sugar donor to the

recipient by forming a glycosidic bond. Most of the active sugar-based donors are uridine diphosphate (UDP)-activated sugar-containing compounds, including UDP-glucose, UDP-galactose, UDP-glucuronic acid, UDP-rhamnose, UDP-xylose, UDP-arabinose. Finally, glycosyltransferase catalyses the transfer of the remaining sugar to the aglycone to generate glycosides according to the preference of the glycosyl donor, glycosyltransferases are different (Yang *et al.*, 2018).

Table 2 shows recent research on the presence of glycosides obtained from plant extracts of the genus *Tagetes*. Interestingly, the identification of each molecule presents a different biological activity, among the most important activities, contraceptive, antimicrobial, acaricidal, antifungal and anti-inflammatory effects have been described (Table 2). Quercetagetin has been the most frequently found molecule in most species of the genus *Tagetes*, with the exception of *T. multiflora*. In addition to these benefits for human health, glycosides are useful in the food and pharmaceutical industry.

Table 2. Some glycosides isolated in species of *Tagetes* genus.

Analysed species	Biological activity	Isolated glycoside	References
T. lucida	Anticonceptive	Quercetagetin-7-O-β-D-glucoside	González-Trujano *et al.*, 2019
T. minuta	Antimicrobial	Quercetagetin-7-arabinosyl-galactoside	Dos-Santos *et al.*, 2017
	Anti-inflammatory	2,3-bis-(galloyl-3,5-dimethyl ether)-(α/β)-D-glucopyranose	Sabrin *et al*., 2018
T. maxima	Antimicrobial	Quercetagetin 7-O-(6-O-caffeoyl-b-D-glucopyranoside) Quercetagetin 7-O-(6-O-coumaroyl-D-β glucopyranoside) Kercetagetin 7-O-(6-O-galloyl-b-D-glucopyranoside)	Parejo *et al*., 2005
T. patula	Acaricide	Kaempferol-3-O-di-Hexoside Quercetin-3-O-di-Hexoside-galloyl	Sanches-Politi *et al*., 2012
	Antibacterial Antifungal	7-O-patuletin glycoside	Faizi *et al*., 2008

	NA	2-metil-6-2,7-octadieno-1-O-β-d-glucopiranoside	Riaz *et al*., 2020
	NA	Quercetin 7-O-glucoside	Halbwirth *et al*., 2004
T. multiflora	NA	Letelin-7-O-glucoside	Xu *et al*., 2012
T. filifolia	Deworming potentian	Quercetagetin	Jasso-Díaz *et al*., 2017

NA = Not assigned.

2.4. Phenolic compounds

Phenolic compounds are part of one of the most abundant groups within secondary metabolites (Martín-Gordo, 2018). To understand the chemical structure of phenolic compounds it is important to start with the phenol molecule (Fig. 2), which is the basic molecule, since the presence of the aromatic ring causes weak acids, generating an inductive effect on the hydrogen of the hydroxyl group.

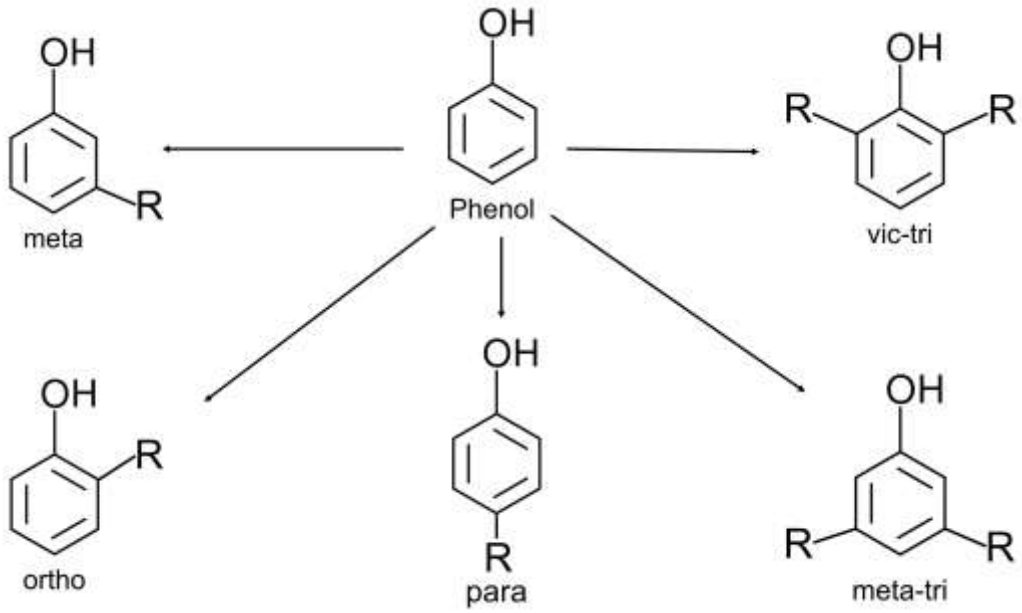


Figure 2. Chemical structure of phenol and simple phenols molecules.

Flavonoids, also known as bioflavonoids, form a group of about 3,000 phenolic compounds that have a similar chemical structure, providing them with important functional properties when consumed. These metabolites are present in all plant families, especially in fruits, vegetables, and herbs. In fact, they have recently reported as phytotherapeutic compounds against SARS-CoV-2 infection (Martín-Gordo, 2018; Coppola and Mondola, 2020). Several flavonoids have been identified in *T. patula* extracts, all belonging to the flavonol group (Fig. 3a) and just one different, belonging to the xanthophyll's group, the lutein (Fig. 3b).

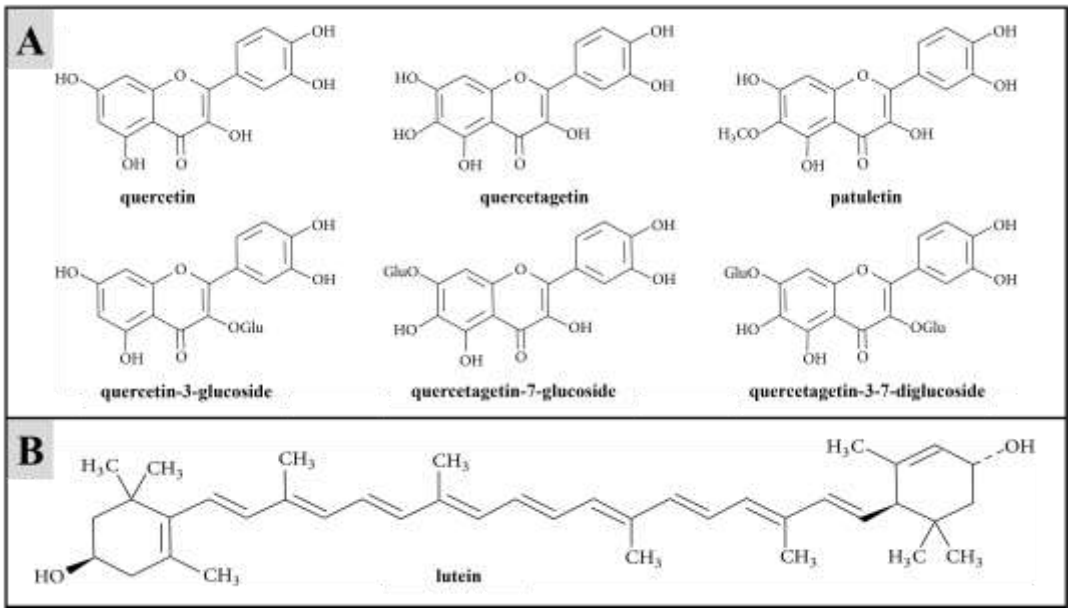


Figure 3. Some secondary metabolites found in *T. patula*. A) Flavonols. B) xanthophylls.

The entire plant uses to prepare traditional remedies against rheumatism, gastrointestinal problems, kidney and liver disorders, fever, and pneumonia. In Europe and Asia, the infusion of its flowers is also applicate as eyewash (Chkhikvishvili *et al.*, 2016).

Table 3. Biological function of some phenolic compounds in *Tagetes* genus.

Analysed species	Phenolic compounds	Biological function	References
T. erecta and *T. patula*	Simple phenols	Antioxidant, antibiotic, antiparasitic, and cytotoxic activities	Martins *et* al., 2016; Parr and Bolwell, 2000
T. erecta and *T. minuta*	Hydroxybenzoic acids	Protective effect against liver lesions in animal models	Khadem and Marles, 2010; Szopa *et al*., 2013
T. erecta and *T. maxima*	Hydroxycinnamic acids	Antioxidant capacity, antigenotoxic and antiproliferative activity	Wang *et al*., 2018
T. lucida	Coumarin	Antioxidant activity and antibacterial properties	Hussain *et al*., 2019
T. erecta and *T. patula*	Quinones	Redox properties and antioxidant activity	El-Najjar *et al*., 2011; da Silva-Júnior *et al*., 2019
T. erecta and *T. patula*	Betacyanins	*In vitro* antioxidant activity	Sakuta, 2014; Taira *et al*., 2015
T. lucida	Lignans	Antioxidant capacity and sources of phytoestrogens in diet	Basu and Maier, 2018; Vo *et al*., 2018
T. erecta	Chalcones	Antibacterial and antioxidant properties	Kar-Mahapatra *et al*., 2019
T. erecta	Flavanones y flavanonols	Inhibitor of the synthesis and secretion of lipids in human hepatocellular hepatic carcinoma (HepG2) cells and anti-inflammatory properties	Pollastri and Tattini, 2011; Górniak *et al*., 2019

T. minuta and *T. patula*	Isoflavones	Antioxidant activity with anti-inflammatory and vasodilator effects	Basu and Maier, 2018; Molina *et al*., 2018
T. erecta, *T. mendocina* and *T. patula*	Catechins	Inhibitor of arterial thrombosis, antioxidant capacity, and anti-inflammatory and anticancer activity	Cheng *et al*., 2020; Shafabakhsh *et al*., 2020
T. erecta, *T. minuta* and *T. patula*	Anthocyanins	Antioxidant capacity and associated with the prevention of obesity, coronary heart disease and cancer	Lee *et al*., 2017; Bendokas *et al*., 2020
T. erecta and *T. minuta*	Gallotannins	Antioxidant and antibacterial activity	Al-Halabi *et al*., 2011; Park *et al*., 2019
T. erecta and *T. minuta*	Ellagitannins	Antibacterial activity	Landete, 2011; Hussein and Khalifa, 2014

The cinnamic acid synthetized from phenylalanine can constitute diverse groups as coumarins, chalcones, flavonols, flavonoids, lignins, lignans (Martín-Gordo, 2018). According to Peñarrieta *et al.*, (2014), the antioxidant power of polyphenols found in species of the *Tagetes* genus produces a variety of beneficial effects for humans, which can consult in Table 3. For the particular case of *T. erecta*, some of the phenolic compounds that have been report are gallic acid, protocatechuic acid, chlorogenic acid, vanillic acid, caffeic acid, cumaric acid, syrup acid, ferulic acid, and synaptic acid (Kaisoon *et al.*, 2011).

3. *Tagetes erecta*, taxonomic classification and main distribution in Mexico

T. erecta is a native plant of Mexico and Central America (Laosinwattana *et al.*, 2018), and traditionally known as marigold. The taxonomic classification of this plant, according to Carlos Linneo (1753) is the following: Kingdom: Plantae; Subkingdom: Tracheobionta; Superdivision: Spermatophyta; Division: Magnoliophyta; Class: Magnoliopsida; Order: Asterales; Family: Asteraceae; Subfamily: Asteroideae; Tribu: Tageteae; Genus: *Tagetes*; Species: *T. erecta* L.

T. erecta grows erect and can reach a height of up to 1.8 m, with a striated, glabrous or pubescent stem. It has opposite leaves at the bottom and alternate at the top, up to 20 cm long. The inflorescences can be solitary or grouped on peduncles up to 15 cm long, provided with pinnate bracts with bristle segments at the apex (Rzedowski and Rzedowski, 2001). Develops in a wide altitudinal range, between 100 and 2300 masl, in several tropical ecosystems, such as deciduous forests, thorn forests, pine-oak forests and cloud forests. This plant can commonly find by associating with wild herbaceous species or with commercial crops. It has a long flowering period that extends throughout the summer and fall (Villaseñor and Redonda-Martínez, 2009).

The soil requirements of *T. erecta* are wide, from sandy to clay soils, which must be well drained and have a low content of organic matter. A very fertile soil tends to promote the production of foliage to the detriment of inflorescences (Attia and Elhawat, 2021). It has been distributed, cultivated and used due to its multiple properties around the world. Particularly in Mexico can be found in the following states: Aguascalientes, Campeche, Chiapas, Coahuila, Colima, CDMX, Durango, Guerrero, Hidalgo, Jalisco, Estado de México, Michoacan, Morelos, Nayarit, Oaxaca, Puebla, Queretaro, Quintana Roo, San Luis Potosi, Sinaloa, Sonora, Tabasco, Tamaulipas, Tlaxcala, Veracruz, Yucatan and Zacatecas (Villaseñor and Espinosa, 1998; Gómez-Rodríguez and Zavaleta-Mejía, 2001; Palacios-Torres *et al.,* 2010; Barajas-Rodríguez *et al.,* 2020).

3.1. Ethnopharmacological relevance of *T. erecta* in Mexico

The flowers of *T. erecta* have colours that varies from weak yellow to intense orange and are very aromatic, an important characteristic that make them very useful in industries such as textiles and food in several parts of the world. Some species of the genus *Tagetes* are also employ as remedies to treat several health problems, including dental, stomach, intestinal, emotional, nervous disorders and even muscle pain (Salehi *et al.,* 2018).

In Latin American world region, this species has been employed for culinary and medicinal purposes. For example, ancient American tribes used this species to wash their skin and disinfect wounds (Gupta and Ur-Rahman, 2015). Currently, in Mexico *T. erecta* is cultivated for ornamental, medicinal and traditional purposes, especially in religious ceremonies such as the "Day of the Dead" in Mexico (Villaseñor and Redonda-Martínez, 2009; Pacheco-Pantoja *et al.,* 2021), although it has also been registered as a weed in the main crop in this country, corn.

The use of *T. erecta* lies mainly in the flowers, which are prepared in infusion and are used in the treatment of gastrointestinal diseases, stomatitis, dyspepsia, colic, parasites, toothache, vomiting and diarrhoea (Gupta and Ur-Rahman, 2015; Ventura-Martínez *et al.,* 2018; Meurer *et al.,* 2019). The pharmacological properties of *T. erecta* leaf and flower extracts using solvents of different polarities. Some of these pharmacological properties are showing in Table 4.

Table 4. Biological properties of *T. erecta*.

Activity	Part of the plant and extracts analyzed	Application	References
Antibacterial	Extract with solvents of different polarity	Used against gram negative bacteria	Gopi *et al*., 2012
	Ethanolic extracts of leaves and flowers		Camacho-Campos *et al*., 2019
	Methanolic extracts	Inhibitory action against the strain of *Neisseria gonorrhoeae*	Ruddock *et al*., 2011
Antioxidant	Ethanolic extracts of flowers	Intense reducing power, even greater than ascorbic acid	Gopi *et al*., 2012
Hepatoprotective	Flower extract in carbon tetrachloride	Hepatoprotective agent that decreases bilirubin levels	Giri *et al*., 2011
Antifungal and anticancer	Ethanolic extract from petals	Fungal species inhibitor	Varahi-Vedam *et al*., 2019
Insecticide, mosquitocide and larvicide	Flower extract in chloroform, ethanol, petroleum ether	Pesticide and mosquitocidal activity	Gopi *et al*., 2012

Nematicide	Leaf extracts	Inhibit the growth and development of the plant parasite *Meloidogyne incognita*	Hussain and Bora, 2008
Wound healing	Hydroalcoholic extract	Healing agent	Gopi *et al*., 2012
Painkiller	Flower extracts	Anti-inflammatory and analgesic agent	Bashir and Gilani, 2008

4. Conclusions and perspectives

The secondary metabolites of the genus *Tagetes* produce different biological activities that humans have taken advantage for their benefit. Moreover, the species of this genus are employed for other activities, mainly as an ornamental resource in the American continent. There are significant number of reference's that contributes to the knowledge about secondary metabolites in the genus. Regarding *T. erecta*, its use in food activities have documented, for example, the use of the lutein contents in the plant for food supplements or the combination of a plant extract with lactic acid for a fabrication of biofilm destined to fatty foods. Nevertheless, the main use and more studied is as traditional medicine. The presence of several bioactive compounds that confer biological activities to *T. erecta*, such as antibacterial, antimicrobial, antioxidant, hepatoprotective, antifungal, anticancer, insecticide and nematicide, well documented in this plant. However, it is necessary to carry out studies on the mechanism of action, bioavailability and its metabolism in humans, as well as its pharmacological effects and to expand the knowledge of the bioactive compounds of *T. erecta* as a strong potential for future clinical and food applications.

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