Review

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Phytochemical Compounds and Their Antibacterial Activity of Species of the Fabaceae Family Located in Tamaulipas, Mexico: Review

Paulina Rachel Gutiérrez-Durán , Jorge Víctor Horta-Vega * , Fabián Eliseo Olazarán-Santibáñez , Juan Flores-Gracia , Hugo Brígido Barrios-García *

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Phytochemical Compounds and Their Antibacterial Activity of Species of the Fabaceae Family Located in Tamaulipas, Mexico: Review

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Abstract

The increasing resistance to antibiotics resulting from their indiscriminate use in humans and animals is a serious public health concern recognized by the WHO and WOAH. In this context, phytotherapy based on medicinal plants represents a promising alternative, particularly due to the presence of bioactive compounds such as flavonoids and alkaloids with antimicrobial potential. The **Fabaceae** family stands out for its remarkable diversity and pharmacological relevance. This review integrates available information on the 347 species recorded in the state of Tamaulipas, Mexico. Only 64 species have been subjected to phytochemical studies, and 46 are traditionally used in medicine, mainly to treat digestive disorders (32%), dermatological conditions (18%), and parasitic infections (15%). The most frequently reported metabolites are tannins and flavonoids, which support their empirical use and therapeutic potential. The main extraction techniques identified were maceration (47.7%) and Soxhlet (10.8%), employing solvents such as methanol (21.5%), water, ethanol, ethyl acetate, and hexane. Herbaceous and arboreal plants were the most investigated. Phenols and flavonoids exhibited antioxidant properties with antibacterial and antifungal activity, whereas alkaloids showed antibacterial, antifungal, anticancer, and anti-inflammatory effects. The greatest metabolic diversity was found in leaves. Microbiological studies highlight notable activity against *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*, mainly evaluated through the disk diffusion method.

Keywords: Fabaceae; traditional medicinal use; bioactive compounds; extraction techniques

1. Introduction

Since ancient times, plants have been used for a wide variety of purposes, including the treatment of diseases due to the presence of bioactive compounds with therapeutic properties, such as the control of infectious diseases in animals and humans [1,2]. Both the World Health Organization (WHO) [3], and the World Organisation for Animal Health (WOAH) [4] have declared antimicrobial resistance to be one of the greatest threats to public health and animal health worldwide [3,4]. For this reason, the current need lies in the search for new alternatives to treat bacterial infections that are resistant to existing antimicrobial agents. One of these alternatives is the exploration of natural compounds, particularly those derived from plants, as they produce secondary metabolites that provide adaptive advantages, such as defense against herbivores and pathogens, and therefore represent potential candidates as medicinal compounds [5–8].

Species belonging to the Fabaceae family are recognized for their chemical diversity and their multiple applications in both traditional and modern medicine [9]. The Fabaceae family comprises

770 genera and nearly 19,500 species worldwide [10]. Their high adaptive capacity defines them as a cosmopolitan family [10,11], with notable diversity in temperate and warm regions, as well as in rainforests, dry forests, and semidesert areas [10,12].

In Mexico, Fabaceae is the second richest family in terms of species, including trees, shrubs, and perennial or annual herbs [10]. Species within this family have significant economic importance, as they are used for food, timber, forestry resources, and forage. Additionally, through symbiosis with bacteria, they contribute to nitrogen fixation in soil [10,12], and some species have also been used in traditional medicine [11,12]. Among their medicinal uses, anti-inflammatory, antiseptic, and antimicrobial properties stand out, attributed to secondary metabolites such as flavonoids, tannins, alkaloids, and saponins, which exert effects on various bacterial microorganisms [9,11].

Although Tamaulipas possesses rich plant biodiversity and a significant ethnobotanical context, the medicinal use of Fabaceae species is limited, and available information mainly derives from community-based knowledge [13]. However, in other regions of Mexico and around the world, studies have been conducted on the antibacterial activity of phytochemical compounds from Fabaceae species against pathogenic bacteria such as *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Salmonella Typhi* [14].

The aim of this study is to provide a comprehensive review of the Fabaceae species present in Tamaulipas and to evaluate whether these species have been the subject of research in Mexico or other regions of the world related to the extraction of chemical compounds with antibacterial, antifungal, or other therapeutic activities.

2. Results and Discussion

2.1. Applications in Traditional Medicine

This study provides a detailed analysis of 347 Fabaceae species from the state of Tamaulipas, distributed across 81 genera. The family is globally recognized for its economic importance, particularly in the areas of food production and human and animal health. Additionally, the characteristics of these species allow their use as timber resources, dyes, resins, and other products [11,15]. This review includes information generated in 16 countries, including Mexico, which accounted for 28% of the studies analyzed; however, none of the reviewed studies correspond to the state of Tamaulipas. Of the total species recorded for the state, the global search revealed that only 64 species have been studied for the extraction of phytochemical compounds, and of these, only 46 have been documented in traditional medicine for the treatment of various ailments (Table 1). In contrast, research conducted in communities within Tamaulipas indicates that the traditional use of Fabaceae comprises only 4–5% of the total plant species present in the region [13].

The traditional uses attributed to these plants (46 species) primarily address digestive ailments, representing 32% of the reported uses. These species are commonly used to manage symptoms such as diarrhea, vomiting, and stomach pain [15,16]. In Mexico, species such as *Prosopis* sp. and *Vachelia* sp., which have a wide distribution, have long been used to treat diarrhea and stomach discomfort [17–19]. The second most common category includes dermatological problems (18%), covering a broad range of skin conditions from mild irritations to severe infections [20–22]. Additionally, 15% of traditional applications focus on the treatment of parasitic infections [23,24].

Fabaceae species are also used to treat renal and urinary problems, respiratory conditions, inflammation, and other therapeutic purposes, due to the presence of active compounds such as tannins, flavonoids, alkaloids, and terpenes, which possess significant biological effects. The fact that these species are used across diverse cultures demonstrates the widespread nature of traditional medicinal knowledge and suggests their usefulness both in ancestral remedies and in contemporary treatments [11].

Table 1. Species of the Fabaceae family recorded in the state of Tamaulipas, including common names and traditional uses.

Botanical name	Synonyms	Common name in México	Traditional use	References (Study location)
Acaciella angustissima (Mill.) Britton & Rose	-	Guajillo	No data recorded	[25] (Queretaro, Mexico)
Aeschynomene indica L.	-	No data recorded	Urticaria, furuncle, nyctalopia, hepatitis, enteritis, and diarrhea.	[21] (Quzhou, China)
Calliandra tergemina (L.) Benth.	-	No data recorded	No data recorded	[26] (Klang, Malaysia)
Canavalia rosea (Sw.) DC.	-	Frijol de playa	No data recorded	[27] (Crato, Brazil)
Canavalia villosa Benth.	-	Gallinitas	No data recorded	[28] (Brazil)
Chamaecrista nictitans (L.) Moench	-	Guajito	Fever and antiviral	[29] (Morelos, Mexico)
Dalea aurea Nutt. ex Pursh	-	No data recorded	Diarrhea, stomach pain, and cramps	[30] (Oklahoma, USA)
Dalea bicolor Humb. & Bonpl. ex Willd.	-	Escobilla	Gastrointestinal problems, vomiting, and diarrhea	[31] (Hidalgo, Mexico)
Dalea foliolosa (Aiton) Barneby	-	Almaraduz	Anti-inflammatory and hypoglycemic	[32] (Oaxaca, Mexico)
Dalea nana Torr. ex A.Gray	-	Trébol enano de pradera	No data recorded	[33] (Arizona, USA)
Dalea versicolor Zucc.	-	No data recorded	No data recorded	[33] (Arizona, USA)
Desmodium incanum (Sw.) DC.	-	Amor seco	Back pain, colds, and kidney Problems	[34] (Manchester, Jamaica)
Desmodium molliculum (Kunth) DC.	-	Hierba de los niños	Infections, body Pain, fever, cough, dyspnea	[35] (Santa Rosa, Ecuador)

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Desmodium scorpiurus (Sw.) Poir.	-	No data recorded	Constipation, cough, convulsions, venereal infections, tinea	[36] (Kaduna, Niger)
Desmodium tortuosum (Sw.) DC.	-	Cadillo	Cardiovascular events	[37] (Ucayali, Peru)
Ebenopsis ebano (Berland.) Barneby & J.W.Grimes	-	Ébano	No data recorded	[38] (Nuevo Leon, Mexico)
Enterolobium cyclocarpum (Jacq.) Griseb.	-	Guanacaste	No data recorded	[39] (Oyo, Niger)
Erythrina herbacea L.	-	Hierba de colorín	No data recorded	[40] (Texas, USA)
Eysenhardtia platycarpa Pennell & Saff.	-	No data recorded	Kidney and gallbladder diseases	[38] (Nuevo Leon, Mexico)
Eysenhardtia polystachya (Ortega) Sarg.	-	Palito azul	Diuretic, kidney and bladder infections	[41] (Hidalgo, Mexico)
Gleditsia aquatica Marshall	-	No data recorded	No data recorded	[42] (Giza, Egypt)
Gleditsia triacanthos L.	-	Acacia de tres espinas	Pain, whooping cough, measles, smallpox, skin diseases, asthma	[22] (South Africa)
Gliricidia sepium (Jacq.) Kunth	-	Cacahuananche	Wounds, diarrhea, repelling mosquitoes, fumigating	[43] (Kerala, India)
Grona adscendens (Sw.) H.Ohashi & K.Ohashi	*Desmodium adscendens* (Sw.) DC.	Amor seco	Oral-dental and urogenital problems, and opportunistic infections	[44] (Ibadan, Niger)
Grona triflora (L.) H.Ohashi & K.Ohashi	*Desmodium triflorum* (L.) DC.	Hierba cuartillo	Diarrhea, convulsions, tonic, diuretic, and biliary conditions.	[45] (Lucknow, India)
Haematoxylum brasiletto H.Karst.	-	Madera de Brasil	Oral and kidney infections, hypertension, gastrointestinal disorders, and diabetes.	[46] (Sonora, Mexico)
Indigofera suffruticosa Mill.	-	Anileira	Healing	[20] (Pernambuco, Brazil)
Inga vera Willd.	-	No data recorded	Treatment of diseases	[47] (Santo Domingo,

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				Dominican Republic)
Leucaena leucocephala (Lam.) de Wit	-	No data recorded	Gastrointestinal	[48] (Ibadan, Niger)
Lonchocarpus punctatus Kunth	-	Balché	Parasitic	[49] (Yucatan, Mexico)
Lysiloma acapulcense (Kunth) Benth.	-	No data recorded	Respiratory, gastrointestinal, urinary, and skin infections	[50] (Baja California, Mexico)
Macroptilium lathyroides (L.) Urb.	-	No data recorded	No data recorded	[51] (Chennai, India)
Mimosa malacophylla A.Gray	-	No data recorded	Diuretic and kidney stones	[52] (Nuevo Leon, Mexico)
Mucuna pruriens (L.) DC.	-	Mucuna	Purgative and diuretic	[53] (Osun, Niger)
Neltuma glandulosa (Torr.) Britton & Rose	*Prosopis glandulosa* Torr.	Mesquite dulce	Gastrointestinal, rashes, eye infections, hernias, skin conditions, sore throat	[54] (Nevada, USA)
Neltuma juliflora (Sw.) Raf.	*Prosopis juliflora* (Sw.) DC.	Mesquite	Colds, diarrhea, flu, hoarseness, inflammation, measles, sore throat, liver and eye problems	[19] (Bushehr, Iran)
Neltuma laevigata (Humb. & Bonpl. ex Willd.) Britton & Rose	*Prosopis laevigata* (Humb. & Bonpl. ex Willd.) M.C.Johnst.	Mesquite	Skin, gastrointestinal, and respiratory diseases	[18] (Zapotitlan Salinas, Mexico)
Neptunia oleracea Lour.	-	Mimosa de agua	Diabetes mellitus, inflammation, and fever	[55] (Selangor, Malaysia)
Pachyrhizus erosus (L.) Urb.	-	Jícama	Skin rashes	[56] (Morelos, Mexico)
Parkinsonia aculeata L.	-	Escoba	Skin and urinary tract infections	[57] (Maharashtra, India)

Parkinsonia florida (Benth. ex A.Gray) S.Watson	-	Palito azul verdoso	No data recorded	[58] (Sonora, Mexico)
Parkinsonia praecox (Ruiz & Pav.) Hawkins	-	Palo brea	Gastrointestinal, antitussive, wound healing, headaches, earaches, and scorpion stings	[59] (Oaxaca, Mexico)
Phaseolus coccineus L.	-	Ayocote	No data recorded	[60] (Dali, China)
Phaseolus lunatus L.	-	Habas	Food	[61] (Machala, Ecuador)
Phaseolus vulgaris L.	-	Frijoles	Food	[62] (Giza, Egypt)
Pithecellobium dulce (Roxb.) Benth.	-	Jungli Jalebi	Earache, leprosy, peptic ulcer, and toothache	[63] (Haryana, India)
Rhynchosia minima (L.) DC.	-	Frijolillo	Skin conditions and to relieve boils.	[64] (Harare, Zimbabwe)
Senegalia berlandieri (Benth.) Britton & Rose	-	Espino	No data recorded	[17] (Texas, USA)
Senegalia greggii (A.Gray) Britton & Rose	-	Tesota	No data recorded	[17] (Texas, USA)
Senna crotalarioides (Kunth) H.S.Irwin & Barneby	-	No data recorded	Inflammation	[65] (San Luis Potosi, Mexico)
Senna hirsuta (L.) H.S.Irwin & Barneby	-	Cuajillo	Hypertension, dropsy, diabetes, fevers, bile, rheumatism, tinea, and eczema	[66] (Uyo, Niger)
Senna obtusifolia (L.) H.S.Irwin & Barneby	-	Tasba	Eye infection and laxative	[67] (Yola, Niger)
Senna occidentalis (L.) Link	-	Candelilla pequeña	Malaria and trypanosomiasis	[68] (Minna, Niger)
Senna pendula (Humb. & Bonpl. ex Willd.) H.S.Irwin & Barneby	-	Pito canuto	Liver diseases and psoriasis	[69] (Ceará, Brazil)

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Senna septemtrionalis (Viv.) H.S.Irwin & Barneby	-	Cafecillo	Diuretic, anti-inflammatory, laxative, expectorant, and fungicide, fever, burns, cholera, hemorrhoids, pain, gastroenteritis.	[70] (Guanajuato, Mexico)
Senna wislizeni (A.Gray) H.S.Irwin & Barneby	-	Carrozo	Laxative properties, skin and parasitic diseases	[23] (Morelos, Mexico)
Sophora tomentosa L.	-	No data recorded	Cholera, diarrhea, gastrointestinal antidote	[71] (Giza, Egypt)
Tephrosia cinerea (L.) Pers.	-	Bardana medicinal	Diarrhea, diuretic, bronchitis, asthma, inflammation	[72] (Chamrajanagar, India)
Vachellia farnesiana (L.) Wight & Arn.	-	Huizache	No data recorded	[17] (Texas, USA)
Vachellia rigidula (Benth.) Seigler & Ebinger	-	Chaparro prieto	No data recorded	[17] (Texas, USA)
Vigna luteola (Jacq.) Benth.	-	Porotillo	No data recorded	[73] (Nantou, Taiwan)
Vigna vexillata (L.) A.Rich.	-	Bejuco pato	No data recorded	[74] (Nantou, Taiwan)
Zapoteca portoricensis (Jacq.) H.M.Hern.	-	Palo blanco	Convulsions, constipation, skin infections	[75] (Abakaliki, Niger)
Zornia diphylla (L.) Pers.	-	Raíz de víbora	Diarrhea and venereal diseases	[76] (Kerala, India)

2.2. Extraction Methods

Table 2 presents the analysis of the most frequently used extraction techniques and solvents. For this section, the biological form of the species and the plant organ employed were considered. Five main extraction techniques were documented: maceration, hydro distillation, percolation, reflux, and Soxhlet. The most widely used method was maceration, applied in 47.7% of the studies due to its operational simplicity and compatibility with thermosensitive compounds, as it is performed at room temperature [77]. This technique, based on the prolonged immersion of plant material in solvents, is accessible for laboratories with limited resources [78,79]. However, it requires large volumes of solvent, the extraction process tends to be lengthy, and aqueous extracts may require preservatives to reduce the risk of microbial contamination [77].

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Table 2. Register of solvents and extraction methods applied to species of the Fabaceae family in Tamaulipas.

Botanical name	Biological form	Organ used	Extraction technique	Solvent	References
Acaciella angustissima (Mill.) Britton & Rose	Shrubby	Seeds	Soxhlet	No data recorded	[25]
Aeschynomene indica L.	Shrubby	Leaves and stems	Hydro-distillation	Distilled water	[21]
Calliandra tergemina (L.) Benth.	Shrubby	Leaves	Maceration	No data recorded	[26]
Canavalia rosea (Sw.) DC.	Herbaceous	Seeds	Purification	Distilled water	[27]
Canavalia villosa Benth.	Climbing	Seeds	Purification	Distilled water	[28]
Chamaecrista nictitans (L.) Moench	Herbaceous	Aerial parts	Maceration	Ethyl acetate	[29]
Dalea aurea Nutt. ex Pursh	Herbaceous	Whole plant	Maceration	Methanol	[30]
Dalea bicolor Humb. & Bonpl. ex Willd.	Shrubby	Whole plant	Maceration	Methanol	[31]
Dalea foliolosa (Aiton) Barneby	Herbaceous	Leaves	Hydro-distillation	Distilled water	[32]
Dalea nana Torr. ex A.Gray	Herbaceous	Roots and aerial parts	No data recorded	No data recorded	[33]
Dalea versicolor Zucc.	Herbaceous	Whole plant	No data recorded	Ethanol and methanol	[33]
Desmodium incanum (Sw.) DC.	Herbaceous	Leaves and flowers	Maceration	Methanol and distilled water	[34]
Desmodium molliculum (Kunth) DC.	Herbaceous	Aerial parts	Maceration	Methanol	[35]
Desmodium scorpiurus (Sw.) Poir.	Herbaceous	Aerial parts	Soxhlet	Petroleum alcohol, chloroform, and methanol.	[36]

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Desmodium tortuosum (Sw.) DC.	Shrubby	Stems and leaves	Reflux	Distilled water	[37]
Ebenopsis ebano (Berland.) Barneby & J.W.Grimes	Arboreal	Seeds	No data recorded	No data recorded	[38]
Enterolobium cyclocarpum (Jacq.) Griseb.	Arboreal	Leaves	Reflux	Ethanol	[39]
Erythrina herbacea L.	Shrubby	Roots	Maceration	Ethyl acetate, n-hexane, acetone	[40]
Eysenhardtia platycarpa Pennell & Saff.	Arboreal	Branches and leaves	Maceration	Distilled water and methanol	[38]
Eysenhardtia polystachya (Ortega) Sarg.	Arboreal	Bark	Reflux	Distilled water	[41]
Gleditsia aquatica Marshall	Arboreal	Fruit	Maceration	Ethanol	[42]
Gleditsia triacanthos L.	Arboreal	Leaf, seeds, and stems	Maceration	Methanol	[22]
Gliricidia sepium (Jacq.) Kunth	Arboreal	Leaf	Maceration	Ethanol	[43]
Grona adscendens (Sw.) H.Ohashi & K.Ohashi	Herbaceous	Root	Maceration	Methanol	[44]
Grona triflora (L.) H.Ohashi & K.Ohashi	Herbaceous	Whole plant	Maceration	Distilled water and methanol	[45]
Haematoxylum brasiletto H.Karst.	Arboreal	Stems	Maceration	Methanol	[46]
Indigofera suffruticosa Mill.	Arboreal	Leaf	Maceration	Acetone, ether, and chloroform	[20]
Inga vera Willd.	Arboreal	Bark	Maceration	Ethanol	[47]
Leucaena leucocephala (Lam.) de Wit	Arboreal	Seeds	Maceration	Hexane	[48]
Lonchocarpus punctatus Kunth	Arboreal	Inflorescence	Maceration	Ethanol	[49]

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Lysiloma acapulcense (Kunth) Benth.	Arboreal	Stems and root	No data recorded	Distilled water	[50]
Macroptilium lathyroides (L.) Urb.	Herbaceous	Leaf	Maceration	Distilled water	[51]
Mimosa malacophylla A.Gray	Shrubby	Leaf	No data recorded	Ethanol	[52]
Mucuna pruriens (L.) DC.	Climbing	Leaf	No data recorded	Methanol	[53]
Neltuma glandulosa (Torr.) Britton & Rose	Arboreal	Leaf	Percolation	Ethanol	[54]
Neltuma juliflora (Sw.) Raf.	Arboreal	Seeds	Maceration	Distilled water, methanol, and ethyl acetate	[19]
Neltuma laevigata (Humb. & Bonpl. ex Willd.) Britton & Rose	Arboreal	Leaf	No data recorded	Methanol	[18]
Neptunia oleracea Lour.	Herbaceous	Leaf and stem	Soxhlet	Methanol	[55]
Pachyrhizus erosus (L.) Urb.	Herbaceous	Seeds	No data recorded	Hexane, dichloromethane, and acetone	[56]
Parkinsonia aculeata L.	Shrubby	Leaf	Soxhlet	Ethanol, methanol	[57]
Parkinsonia florida (Benth. ex A.Gray) S.Watson	Arboreal	Leaf	Reflux	Distilled water	[58]
Parkinsonia praecox (Ruiz & Pav.) Hawkins	Arboreal	Bark	Maceration	Methanol	[59]
Phaseolus coccineus L.	Herbaceous	Seeds	Purification	No data recorded	[60]
Phaseolus lunatus L.	Herbaceous	Seeds	Purification	No data recorded	[61]
Phaseolus vulgaris L.	Herbaceous	Seeds	Purification	Ammonium sulfate	[62]

Pithecellobium dulce (Roxb.) Benth.	Arboreal	Leaf	Maceration	Chloroform, acetone, methanol, and distilled water	[63]
Rhynchosia minima (L.) DC.	Climbing	Leaf	Hydro-distillation	Distilled water	[64]
Senegalia berlandieri (Benth.) Britton & Rose	Shrubby	Leaf	Soxhlet	Ethanol, chloroform, ethyl acetate	[17]
Senegalia greggii (A.Gray) Britton & Rose	Shrubby	Leaf	Soxhlet	Ethanol, chloroform, ethyl acetate	[17]
Senna crotalarioides (Kunth) H.S.Irwin & Barneby	Shrubby	No data recorded	No data recorded	No data recorded	[65]
Senna hirsuta (L.) H.S.Irwin & Barneby	Shrubby	Fruit	No data recorded	No data recorded	[66]
Senna obtusifolia (L.) H.S.Irwin & Barneby	Herbaceous	Leaf	Reflux	Acetone, hexane, methanol	[67]
Senna occidentalis (L.) Link	Herbaceous	Leaf	Maceration	Methanol	[68]
Senna pendula (Humb. & Bonpl. ex Willd.) H.S.Irwin & Barneby	Shrubby	Leaf, flowers, and branches	Maceration	Hexane and ethanol	[69]
Senna septemtrionalis (Viv.) H.S.Irwin & Barneby	Shrubby	Aerial parts	Maceration	Ethanol	[70]
Senna wislizeni (A.Gray) H.S.Irwin & Barneby	Shrubby	Whole plant	Maceration	Methanol and hexane	[23]
Sophora tomentosa L.	Shrubby	Leaf	Maceration	Petroleum ether	[71]

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Tephrosia cinerea (L.) Pers.	Herbaceous	Leaf	No data recorded	Ethyl acetate, acetone, petroleum ether	[72]
Vachellia farnesiana (L.) Wight & Arn.	Arboreal	Leaf	Soxhlet	Ethanol, chloroform, ethyl acetate	[17]
Vachellia rigidula (Benth.) Seigler & Ebinger	Shrubby	Leaf	Soxhlet	Ethanol, chloroform, ethyl acetate	[17]
Vigna luteola (Jacq.) Benth.	Herbaceous	Whole plant	Maceration	Methanol	[73]
Vigna vexillata (L.) A.Rich.	Herbaceous	Whole plant	Maceration	Methanol, chloroform, and distilled water	[74]
Zapoteca portoricensis (Jacq.) H.M.Hern.	Shrubby	Leaf	Maceration	Water, methanol, ethyl acetate, diethyl ether	[75]
Zornia diphylla (L.) Pers.	Herbaceous	Whole plant	Hydro-distillation	Distilled water	[76]

The Soxhlet method, used in 10.8% of the studies, was the second most common technique. It is characterized by its efficiency in the continuous extraction of thermostable compounds and its suitability for volatile solvents. One of its major advantages is the ability to obtain larger extract yields using smaller amounts of solvent. Nevertheless, the continuous extraction at high temperatures makes it unsuitable for plant materials containing thermolabile compounds, which limits its application for certain heat-sensitive metabolites [80,81].

The reflux method was employed in 7.70% of the studies, and hydro distillation in 4.60%. Percolation, applied in only 1.50% of the reviewed studies, was the least used technique. These methods are preferred for obtaining volatile compounds, although their implementation requires more specialized equipment [82,83] (Figure 1).

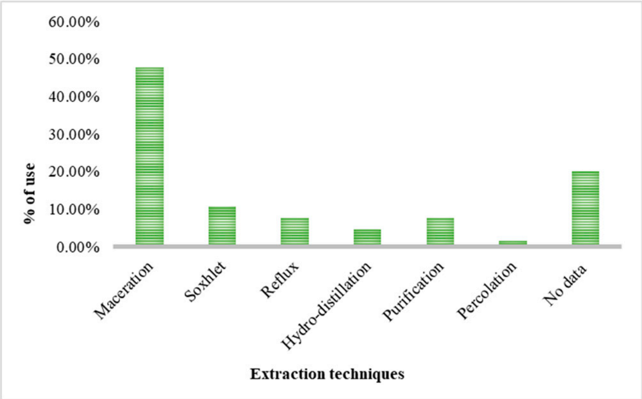

Figure 1. Extraction techniques implemented in the reviewed literature.

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2.2.1. Solvents

The choice of solvent for the extraction of phytochemicals is essential and depends on both the chemical characteristics of the target compounds and the specific plant material used. The type of metabolite sought helps determine the most appropriate solvent, as each compound dissolves more efficiently in solvents of different polarity. Polar compounds are best extracted with solvents such as methanol or ethanol, whereas non-polar metabolites are commonly extracted with solvents such as hexane. The plant organ selected for extraction is also an important factor [81].

Polar compounds typically require solvents such as water, methanol, or ethanol, due to their polar nature. Conversely, non-polar compounds are extracted using non-polar solvents such as hexane or dichloromethane [80]. The most frequently used solvents in the reviewed studies were methanol, distilled water, ethanol, ethyl acetate, acetone, and hexane (Figure 2). Methanol, used in 21.50% of the extraction assays, was the most common solvent; its intermediate polarity facilitates the extraction of a wide range of secondary metabolites [84]. However, its toxicity limits its applicability, as exposure through ingestion, inhalation, or skin contact can pose significant risks.

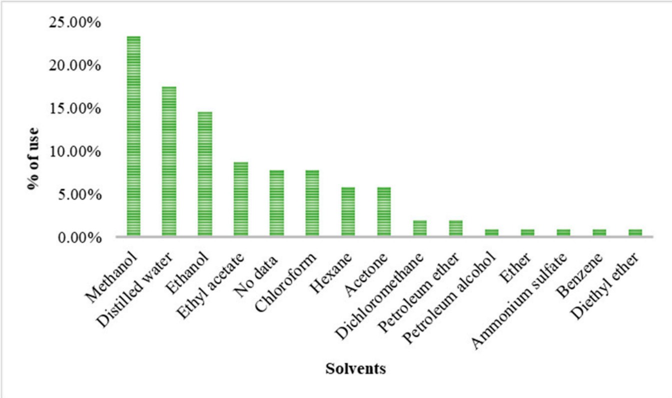

Figure 2. Solvents most commonly used in the extraction of organic compounds.

As safer alternatives, ethanol and distilled water have gained importance due to their favorable safety profiles and, in the case of ethanol, its lower environmental impact [80,85]. Ethanol, in particular, stands out for achieving extraction recoveries of up to 80% for metabolites such as flavanones and triterpenoids [86]. Hexane, a petroleum-derived solvent, presents economic and environmental challenges because its recovery requires substantial energy input, and it is volatile, toxic, and flammable. A less invasive alternative to hexane is ethyl acetate, which offers lower risk, reduced environmental impact, and greater sustainability [87].

2.2.2. Biological Categories

Las The biological form categories of the plant species included shrubs, trees, herbs, and climbers. Herbaceous and tree species were the most frequently studied, accounting for 36% and 31% of the records, respectively. These categories are most commonly collected and analyzed in ethnobotanical studies due to their abundance, availability, and ease of collection in the field, making them more accessible for research. Shrub species followed in lower proportion, and climbers were the least represented (Figure 3) [88,89].

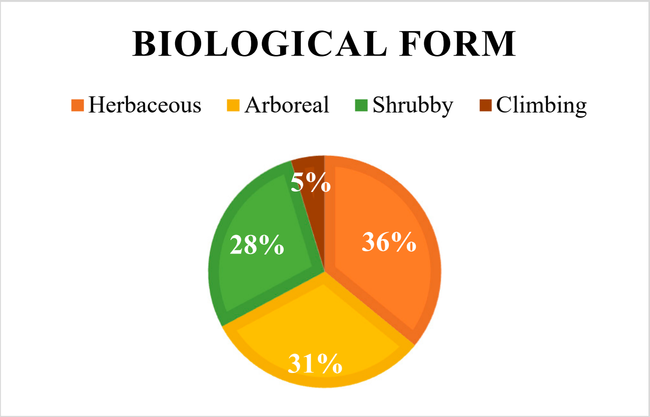

Figure 3. Biological form of species used in tests.

The review shows that, of the 66 published studies, 39% used leaves, as they contain high concentrations of active compounds such as polyphenols and alkaloids, which exhibit antioxidant, anticancer, and anti-inflammatory properties [88,90]. A study on *Dendrobium officinale* demonstrated that its leaves contain higher levels of polyphenols and lipids, supporting their potential as a source of bioactive compounds [91].

Seeds, used in 13.8% of the studies, are valued mainly for their content of essential oils and antioxidant compounds. These metabolites have significant therapeutic applications [92]. The least used organs were stems, bark, inflorescences, fruits, and roots (Figure 4).

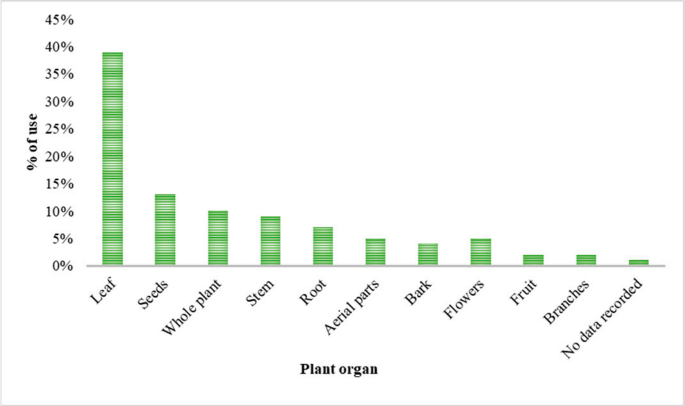

Figure 4. Organ used in extraction tests.

2.3. Isolated Compounds

Table 3 provides a detailed analysis of the bioactive compounds isolated from the studied plant species and their associated therapeutic properties. Phenols and flavonoids were the most common compounds, exhibiting antioxidant, antibacterial, and antifungal activities [93,94]. In addition, the extracts contained alkaloids, tannins, saponins, terpenoids, essential oils, lectins, and isoflavones, each contributing diverse therapeutic effects depending on the isolated compound.

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Table 3. Isolated compounds, bioactive properties, and effects on microorganisms of species of the Fabaceae family.

Botanical name	Isolated compounds	Bioactive properties	Effect on microorganisms	Study/dose used	References
Acaciella angustissima (Mill.) Britton & Rose	Phenols and flavonoids	Antioxidants, antimutagenic, antidiabetic, anticancer, and anti-inflammatory.	*Rhizoctonia solani, Fusarium oxysporum* y *Phytophtora capsici*	Dextrose potato agar culture (200 mg/mL)	[25]
Aeschynomene indica L.	Essential oils	Antibacterial, antioxidant, and cytotoxic	*Staphylococcus aureus* y *Bacillus subtilis*	Broth dilution (0.312–0.625 mg/mL)	[21]
Calliandra tergemina (L.) Benth.	Flavonol	Antioxidant	*Staphylococcus aureus*	Broth dilution (0.02–1.00 mg/mL)	[26]
Canavalia rosea (Sw.) DC.	Lectins	No data recorded	*Candida albicans*	Microdilution (512 to 0.5 µg/mL)	[27]
Canavalia villosa Benth.	Lectins	Hemagglutination activity	No data recorded	No data recorded	[28]
Chamaecrista nictitans (L.) Moench	Flavonoids, ellagic acid, and proanthocyanidin oligomers	Anthelmintic, antioxidant, and prebiotic	*Haemonchus contortus*	Ovicidal activity (2134 and 601 µg/mL)	[29]
Dalea aurea Nutt. ex Pursh	Isoflavones	Anti-amebic	*N. fowleri*	In vitro assay (10 µg/mL)	[30]
Dalea bicolor Humb. & Bonpl. ex Willd.	No data recorded	No data recorded	*Salmonella choleraesuis, E. coli, Staphylococcus aureus Bacillus subtilis Pseudomonas aeruginosa*	Broth dilution (50 and 100 mg/mL)	[31]

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			Salmonella Typhi		
Dalea foliolosa (Aiton) Barneby	Monoterpenes, sesquiterpenes, and aliphatic hydrocarbons	Antioxidant, anti-a-glucosidase	*Pseudomonas syringae*	Microdilution (35–155 µg mL-1)	[32]
Dalea nana Torr. ex A.Gray	Flavonoids	Antimicrobial	*Cryptococcus neoformans, Staphylococcus aureus, Candida albicans.*	Microdilution (6.7–37.0 µM)	[33]
Dalea versicolor Zucc.	Flavonoids	Antimicrobial	*Staphylococcus aureus y Bacillus cereus*	Microdilution (10–30 µg/mL)	[33]
Desmodium incanum (Sw.) DC.	No data recorded.	Antimicrobial	*Staphylococcus aureus, Streptococcus y Klebsiella Pneumoniae*	Well diffusion (5–100 mg/dL)	[34]
Desmodium molliculum (Kunth) DC.	Flavonoids, phenols, terpenes, essential oils, and alkaloids; hypocholesterolemic and hepatoprotective effects.	Antioxidant, antibacterial, anti-inflammatory	No data recorded	No data recorded	[35]
Desmodium scorpiurus (Sw.) Poir.	Alkaloids, saponins, glycosides, steroids, and flavonoids.	Antibacterial	*Pseudomonas aeruginosa, Escherichia coli y Streptococcus pyrogenes*	Broth dilution (200 mg/mL)	[36]
Desmodium tortuosum (Sw.) DC.	Phenols, flavonoids, carotenoids.	Antioxidant	No data recorded	Microdilution (200 µg/mL)	[37]

Ebenopsis ebano (Berland.) Barneby & J.W.Grimes	Phenols.	Antimicrobial	*Escherichia coli, S. enterica* y *Candida albicans*	Colorimetric assay (125–500 mg/mL)	[38]
Enterolobium cyclocarpum (Jacq.) Griseb.	Phenols	Antimicrobial	*Serratia liquefaciens y Staphylococcus warneri*	Disc diffusion (10 µl)	[39]
Erythrina herbacea L.	Alkaloids	No data recorded	*Staphylococcus aureus*	Microdilution (6.25–50 µg/mL)	[40]
Eysenhardtia platycarpa Pennell & Saff.	No data recorded	Anti-inflammatory, antifungal	No data recorded	No data recorded	[38]
Eysenhardtia polystachya (Ortega) Sarg.	Anthraquinones, cardiac glycosides, coumarins, reducing sugars, saponins, and tannins	Blood purifier, antitussive, antispasmodic, antidiabetic, febrifuge, anti-inflammatory, antirheumatic, and analgesic	No data recorded	In vivo activity (500 and 750 mg/kg)	[41]
Gleditsia aquatica Marshall	Saponins	Cytotoxic	No data recorded	No data recorded	[42]
Gleditsia triacanthos L.	No data recorded	Analgesic, anti-inflammatory, hepatoprotective, and antimicrobial activity	*Proteus spp., Streptococcus spp., E. coli y Enterobacter spp. y one yeast species viz. C. albicans.*	Well diffusion (1000, 500, 250, 125, 62.5 and 31. 25 µg/mL)	[22]
Gliricidia sepium (Jacq.) Kunth	Glycosides, phytosterols, alkaloids, oils, saponins, phenols, and flavonoids	Antibacterial, antifungal, antiviral, and antioxidant	*Escherichia coli y Pseudomonas aeroginosa*	Disc diffusion (0.1g/1ml)	[43]
Grona adscendens (Sw.) H.Ohashi & K.Ohashi	Tannins, saponins, alkaloids,	Antimicrobial	*Staphylococcus aureus, Candida albicans*	No data recorded (0.25 - 0.50 mg/ml)	[44]

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	and flavonoids				
Grona triflora (L.) H.Ohashi & K.Ohashi	Alkaloids, steroids, tannins, saponins, and flavonoids	Antispasmodic, sympathomimetic, central nervous system stimulant, and diuretic	*Staphylococcus aureus, Micrococcus luteus, Bacillus pumilus, Pseudomonas aeruginosa, Pseudomonas fluorescens, Escheria coli*	Disc diffusion (50 and 100 µg/ml)	[45]
Haematoxylum brasiletto H.Karst.	Flavonoids	Antimicrobial	*Candida albicans*	Disc diffusion (8.7 to 128 µg/mL)	[46]
Indigofera suffruticosa Mill.	Alkaloids, flavonoids, phenylpropanoids, triterpenoids, volatile oils	Anti-inflammatory and anticonvulsant	*Staphylococcus aureus*	Disc diffusion (0.78 - 6.25 mg/mL)	[20]
Inga vera Willd.	No data recorded	Antimicrobial	*Escherichia coli, Klebsiella pneumoniae, Staphylococcus aureus, Pseudomona aeruginosa, y Candida albicans*	Disc diffusion (35 µg/mL)	[47]
Leucaena leucocephala (Lam.) de Wit	Essential oils	Central nervous system depressant, anthelmintic, and antidiabetic	*Staphylococcus aureus, Esherichia coli, Bacillus subtilis y Pseudomonas aeruginosa, Aspergilus niger, Rhizopus stolon, Penicillum*	Microdilution (100µg/ml, 50µg/ml, 25µg/ml, 12.5µg/ml)	[48]

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			notatum y Candida albicans		
Lonchocarpus punctatus Kunth	Alkaloids, camptothecins, epipodophyllotoxins, and taxanes	Anticancer	No data recorded	Colorimetric assay	[49]
Lysiloma acapulcense (Kunth) Benth.	Tannins	Antimicrobial	*E. coli, P. aeruginosa, S. aureus y C. albicans*	Well diffusion (2.5 μg/mL to 5.0 μg/mL)	[50]
Macroptilium lathyroides (L.) Urb.	Flavonoids, polyphenols, terpenoids, saponins, and alkaloids	Antioxidant, antibacterial, cytotoxic, anticancer, and antifungal.	*Staphylococcus aureus and Escherichia coli*	Disc diffusion (1000 μg/mL, 750 μg/mL, and 500 μg/mL)	[51]
Mimosa malacophylla A.Gray	No data available	No data	*Stenotrophomonas maltophilia*	Well diffusion (2.9 ± 0.5 mg/mL-1)	[52]
Mucuna pruriens (L.) DC.	No data available	Astringent, laxative, anthelmintic, alexipharmic, and tonic	*Staphylococcus aureus, Escherichia coli, Bacillus subtilis, Pseudomonas aeruginosa*	Well diffusion (240 mg/mL)	[53]
Neltuma glandulosa (Torr.) Britton & Rose	Alkaloids	Antibacterial, antifungal, anti-infective, and antiparasitic activity	*Leishmania donovani, Plasmodium falciparum, Cryptococcus neoformans, Mycobacterium intracellulare*	Microdilution (0.66-20 μg/mL)	[54]
Neltuma juliflora (Sw.) Raf.	Alkaloids	Antibacterial	*Staphylococcus aureus, Staphylococcus epidermidis, Escherichia coli*	Broth dilution (2.5 mg/mL)	[19]

Neltuma laevigata (Humb. & Bonpl. ex Willd.) Britton & Rose	Phenols and alkaloids	Antimicrobial and antioxidant	*y Pseudomonas aeruginosa Staphylococcus aureus , Escherichia coli , Candida tropicalis* y *Fusarium moniliforme*	Broth dilution (0.08-4.62 mg/mL)	[18]
Neptunia oleracea Lour.	Alkaloids, glycosides, flavonoids, proteins, terpenoids, phytosterols, and tannins	Antioxidants and anti-inflammatory	*Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa y Candida albicans*	Disc diffusion (10-100 mg/mL)	[55]
Pachyrhizus erosus (L.) Urb.	Isoflavones	Antifungal	C. *gloeosporioides, F. oxysporum,* y *R. stolonifer*	Disc diffusion (0.5–250 µg/mL)	[56]
Parkinsonia aculeata L.	Alkaloids, glycosides, flavonoids, terpenoids, and tannins	Antibacterial	*Staphylococcus aureus, Escherichia coli,* y *Pseudomonas aeruginosa*	Disc diffusion (12.5–50 mg/mL)	[57]
Parkinsonia florida (Benth. ex A.Gray) S.Watson	Alkaloids, carbohydrates, saponins, phenols, flavonoids, proteins, cardiac glycosides	Antibacterial	*Staphylococcus aureus* y *Escherichia coli.*	Disc diffusion (125–2000 µg/mL)	[58]
Parkinsonia praecox (Ruiz & Pav.) Hawkins	Triterpenes	Anticancer, antibacterial	*Listeria monocytogenes*	Microdilution (2000 µg/mL)	[59]
Phaseolus coccineus L.	Lectins	Antinoplastic and antifungal.	*Candida albicans, Penicillium italicum,*	Disc diffusion (31.3–250 mg/mL)	[60]

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			Helminthosporium maydis, Sclerotinia sclerotiorum, Gibberalla sanbinetti y *Rhizoctonia solani*		
Phaseolus lunatus L.	Isolated and hydrolyzed proteins	Antibacterial, antioxidant, anti-inflammatory	*Staphylococcus aureus, Escherichia coli, Bacillus cereus, Listeria monocytogenes* y *Pseudomonas aeruginosa*	Well diffusion (500, 375, 250, 200, and 150 mg/mL)	[61]
Phaseolus vulgaris L.	Lectins	Antibacterial and antifungal	*Staphylococcus aureus ATCC 6538, and Streptococcus mutants ATCC 25175, Pseudomonas aeruginosa ATCC 10145 and Klebsiella pneumonia*	Microdilution (0.24–1000 μg/mL)	[62]
Pithecellobium dulce (Roxb.) Benth.	Alkaloids, anthraquinones, flavonoids, cardiac glycosides, proteins, tannins, sugars, and terpenoids.	Anti-inflammatory, antivenom, protease inhibitor, spermicide, antimicrobial, and antituberculosis activity	*Bacillus subtilis, Enterococcus faecalis, Micrococcus luteus, Staphylococcus aureus and Staphylococcus epidermidis), Aeromonas hydrophila, Alcaligenes faecalis, Enterobacter*	Microdilution (200–1000 μg/mL)	[63]

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			aerogenes, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa y Salmonella typhimurium		
Rhynchosia minima (L.) DC.	Essential oils	Antimicrobianas y antioxidantes	*Acenotobacter calcoacetilus, Bacillus subtilis, Citrobacter freundii, Escherichia coli, Proteus vulgaris, Pseudomonas aeruginosa, Salmonella typhii, Staphylococcus aureus* y *Yersinia enterocolitica.*	Well diffusion (100 µg/mL)	[64]
Senegalia berlandieri (Benth.) Britton & Rose	No data recorded	Antibacterial	No antibacterial effects observed	Disc diffusion (100 mg/mL)	[17]
Senegalia greggii (A.Gray) Britton & Rose	No data recorded	Antibacterial	No antibacterial effects observed	Disc diffusion (100 mg/mL)	[17]
Senna crotalarioides (Kunth) H.S.Irwin & Barneby	No data recorded	Anti-inflammatory	No data recorded	No data recorded	[65]
Senna hirsuta (L.) H.S.Irwin & Barneby	Essential oils	Antimicrobial	*Escherichia coli, Staphylococcus aureus,*	Microdilution (78-625 µg/mL)	[66]

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		Antimicrobial	*Bacillus subtilis* y *Aspergillus niger*		
Senna obtusifolia (L.) H.S.Irwin & Barneby	Saponins, tannins, alkaloids, and flavonoids.		*Neisseria gonorrheae, Salmonella sp., Pseudomonas aeruginosa, Proteus vulgari, Staphylococcus aureus* y *Streptococcus aerugenosa*	Disc diffusion (200 - 1000 µg/mL)	[67]
Senna occidentalis (L.) Link	Tannins, alkaloids, glycosides, flavonoids, steroids, saponins, anthraquinones, and flobanoids	Antimalarial, antitrypanosomal, immunosuppressive, anti-inflammatory, larvicidal, antidiabetic, anticancer, antiulcer, and hepatoprotective.	*Escherichia coli, Klebsiella pneumoniae, Candida albicans, Staphylococcus aureus, Pseudimonas aeruginosa* y *Salmonella typhi*	Well diffusion (80 and 120 mg/mL)	[68]
Senna pendula (Humb. & Bonpl. ex Willd.) H.S.Irwin & Barneby	Anthraquinones, steroids, flavones, flavonols, saponins, tannins, triterpenoids, xanthones	Inflammatory, antimicrobial, antitumor, antimalarial, cardioprotective, and antioxidant.	No studies on M.O. are presented.	No data recorded	[69]
Senna septemtrionalis (Viv.) H.S.Irwin & Barneby	No data recorded	Diuretic activity and neuropharmacological effects	No studies on M.O. are presented.	No data recorded	[70]
Senna wislizeni (A.Gray)	Flavonols	Laxative, antimicrobial, antiviral,	*Escherichia coli* y *Salmonella thyphimurium*	Agar overlay bioautography	[23]

H.S.Irwin & Barneby		antifungal, anti-inflammatory, antitumor, antioxidant			
Sophora tomentosa L.	Hydrocarbons, sterols, terpenes	Antioxidants, antimicrobials, anti-inflammatories, and anticancer agents	*B. subtilis, S. aureus y E. coli*	Well diffusion (50 mg/mL)	[71]
Tephrosia cinerea (L.) Pers.	Phenols	Antimicrobial	*Pseudomonas aeruginosa, E. coli*	Broth dilution (10-90 mg/mL)	[72]
Vachellia farnesiana (L.) Wight & Arn.	Phenols, tannins, diterpenes, sterols, triterpenes, and saponins	Antibacterial	*M. roseus*	Disc diffusion (100 mg/mL)	[17]
Vachellia rigidula (Benth.) Seigler & Ebinger	Phenols, tannins, diterpenes, sterols, triterpenes, and saponins	Antibacterial	*P. alcalifaciens*	Disc diffusion (100 mg/mL)	[17]
Vigna luteola (Jacq.) Benth.	Flavonoids and isoflavonoids	Antioxidant, antifungal, antitumor, antiparasitic, hypoglycemic, hepatoprotective, renal protection, antibacterial, hypotensive, and hypolipidemic	No studies on M.O. are presented.	No data recorded	[73]
Vigna vexillata (L.) A.Rich.	Sterols and isoflavones	Hypoglycemia, antihypertensive, cholesterol-	No studies on M.O. are presented.	No data recorded	[74]

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		lowering, antioxidant, antibacterial, anticancer			
Zapoteca portoricensis (Jacq.) H.M.Hern.	Alkaloids, saponins, tannins, terpenoids, flavonoids	Antimicrobial, antiviral, antioxidant	*S. aureus, S.pyogenes, E. coli, K. pneumoniae, P. aeruginosa, C. albicans, M. audouini*	Disc diffusion (5.0, 10.0, 20.0 mg/mL)	[75]
Zornia diphylla (L.) Pers.	Essential oils	Antifungal, antimicrobial	*Salmonella typh*	Microdilution (50 μg/mL)	[76]

2.3.1. Properties of the Main Isolated Compounds

Phenols and flavonoids: These are the most common antioxidants in plants and exhibit antibacterial and antifungal activities [25,26]. The antibacterial mechanisms of flavonoids include inhibition of nucleic acid synthesis, disruption and damage of the bacterial cytoplasmic membrane, and inhibition of biofilm formation [95].

Alkaloids: Their mechanism of action primarily involves the disruption and destruction of the bacterial cell membrane. Alkaloids demonstrate broad-spectrum activity against both Gram-positive and Gram-negative bacteria [96].

Tannins: They exhibit antimicrobial, antidiabetic, and anti-inflammatory properties [36,47]. These compounds are soluble in water, alcohol, and acetone, and by interacting with proteins in the bacterial plasma membrane, they interfere with enzymatic function and inhibit microbial activity [97].

Saponins: They display cytotoxic activity through induction of cell death in both tumor and normal cell lines, which limits their use in consumer products [98].

Terpenoids: Although less frequent, they possess antimicrobial and antifungal activities. Their high lipid affinity and low molecular weight allow them to interact with and disrupt the cell membrane, leading to cell death or inhibiting key fungal processes such as germination and sporulation [99].

Essential oils: Their hydrophobic nature disrupts the lipid structure of cell membranes, increasing permeability and causing leakage of intracellular contents, resulting in cell death. They exhibit strong antimicrobial activity, particularly against Gram-positive bacteria [99,100].

Lectins: They exhibit antibacterial properties by inhibiting bacterial growth through recognition of specific carbohydrates present on bacterial surfaces, triggering immune responses without necessarily causing bacterial death [101].

2.4. Evaluated Microorganisms

The effects of the isolated compounds have been evaluated primarily against the following microorganisms:

A) ***Staphylococcus aureus*** (Gram-positive bacterium), a clinically important pathogen. Studies indicate that it is particularly sensitive to phenols, flavonoids, alkaloids, and essential oils [14,102,103].

B) ***Escherichia coli*** (Gram-negative bacterium), inhibited by tannins, terpenoids, and hydrolyzed proteins. Tannins modulate the bacterial cell membrane, while specific terpenoids produce

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significant inhibition zones (5.5–6 mm). Antimicrobial flavonoids act by inhibiting DNA gyrase, thereby affecting cell replication [14].

C) ***Candida albicans*** (yeast-like fungus), which exhibits sensitivity to lectins, flavonoids, and essential oils [14,103].

Other evaluated microorganisms include Gram-positive bacteria (*Bacillus subtilis*, *Listeria monocytogenes*), Gram-negative bacteria (*Pseudomonas aeruginosa*, *Pseudomonas syringae*, *Neisseria gonorrhoeae*, *Salmonella* spp., *Proteus vulgaris*), filamentous fungi (*Aspergillus niger*, *Fusarium oxysporum*, *Penicillium italicum*, *Rhizoctonia solani*), yeasts (*Cryptococcus neoformans*, *Candida tropicalis*), phytopathogenic fungi (*Colletotrichum gloeosporioides*, *Helminthosporium maydis*, *Sclerotinia sclerotiorum*), and pathogenic parasites (*Leishmania donovani*, *Plasmodium falciparum*, *Naegleria fowleri*) (Table 3).

It is important to note that tannins exhibit stronger activity against Gram-positive bacteria compared to Gram-negative ones, with their action being slower due to the double membrane characteristic of the latter [104]. Conversely, terpenoids such as carvacrol, limonene, and linalool act against both groups, showing greater effectiveness against *S. aureus*, *E. coli*, and *Salmonella* spp., while *Pseudomonas* spp. and *Streptococcus* spp. tend to be more resistant [14].

2.5. Antimicrobial Evaluation Techniques

A variety of methods were employed to assess the antimicrobial effects of the plant extracts, with a total of 10 different techniques identified. Approximately 70% of the methodologies were primarily focused on bacterial testing. Among the most frequently used assays, disk and well diffusion emerged as the predominant technique, applied in 47.17% of the analyzed studies, followed by microdilution variants, which accounted for 19.81% of the cases. This distribution aligns with the widespread acceptance and applicability of these techniques in microbiology due to their simplicity, low cost, and ease of implementation. Notably, 15.11% of the reviewed studies did not report the specific technique used [105].

The disk diffusion method is an in vitro assay that determines the susceptibility of microorganisms to antimicrobial agents by observing inhibition zones around disks impregnated with the compound of interest. Its popularity stems from several advantages: it is a relatively rapid and straightforward technique, suitable when evaluating multiple compounds against various microorganisms, and it does not require sophisticated equipment or large quantities of reagents, making it accessible for laboratories with limited resources [106].

However, disk diffusion presents inherent limitations. The results are primarily qualitative or semiquantitative, indicating microbial susceptibility or resistance but not providing an exact measurement of the minimum inhibitory concentration (MIC). Additionally, the method can be influenced by factors such as the solubility of the tested compound, the composition of the culture medium, and the growth rate of the microorganism [107].

3. Materials and Methods

An assessment of the species richness of the Fabaceae family in the state of Tamaulipas was conducted based on documented records. Species records were obtained from Villaseñor's *Plantas vasculares de México* [108], which reports 347 species for the region; these were used as the reference dataset for the present analysis.

Using these records, a detailed systematic review was performed through Google Scholar, Web of Science, PubMed, and SciELO. This review includes information generated in 16 countries. The search criteria applied to each of the 347 Fabaceae species were: (a) phytochemical extracts, (b) antimicrobial activity of extracts, (c) bioactive compounds, (d) phytocompounds, and (e) medicinal use. All studies combining these keywords and providing relevant information were included, regardless of publication year or language. Articles lacking essential information were considered non-relevant and excluded. In total, 109 publications were incorporated into the manuscript, approximately 44% of which were published within the last ten years (2015–2025). Most sources were journals indexed in the *Journal Citation Reports* (JCR), although additional publications containing relevant data were also considered. The review focused on the chemical composition of the species, their traditional uses, the microorganisms affected by the extracts, the plant organs used for extraction, and the solvents employed.

Tamaulipas is recognized for its great diversity of ecosystems, resulting from its varied topography—ranging from coastal areas to elevations of 3,100 m a.s.l.—and its position at the transition between the Nearctic and Neotropical biogeographic regions (Figure 5). The state's climatic diversity includes dry and semi-dry climates, warm sub-humid conditions across most of the territory, and small areas with temperate sub-humid and warm humid climates toward the southwest. These conditions have supported substantial floristic richness, with 4,278 vascular plant species recorded, distributed across 218 families and 1,309 genera [10,108].

Validation of the scientific names of the 347 species was essential to ensure accurate identification and classification. For this purpose, *The Plant List* (plantlist.org) was used to confirm nomenclatural accuracy, and the names of the Fabaceae species were cross-checked using the *Catalogue of Life* (catalogueoflife.org) [109]. This procedure ensures nomenclatural authenticity and prevents potential synonymies that might generate confusion in scientific literature. The combined use of both tools strengthens the reliability and consistency of taxonomic information, ensuring that all names used are globally accepted and recognized.

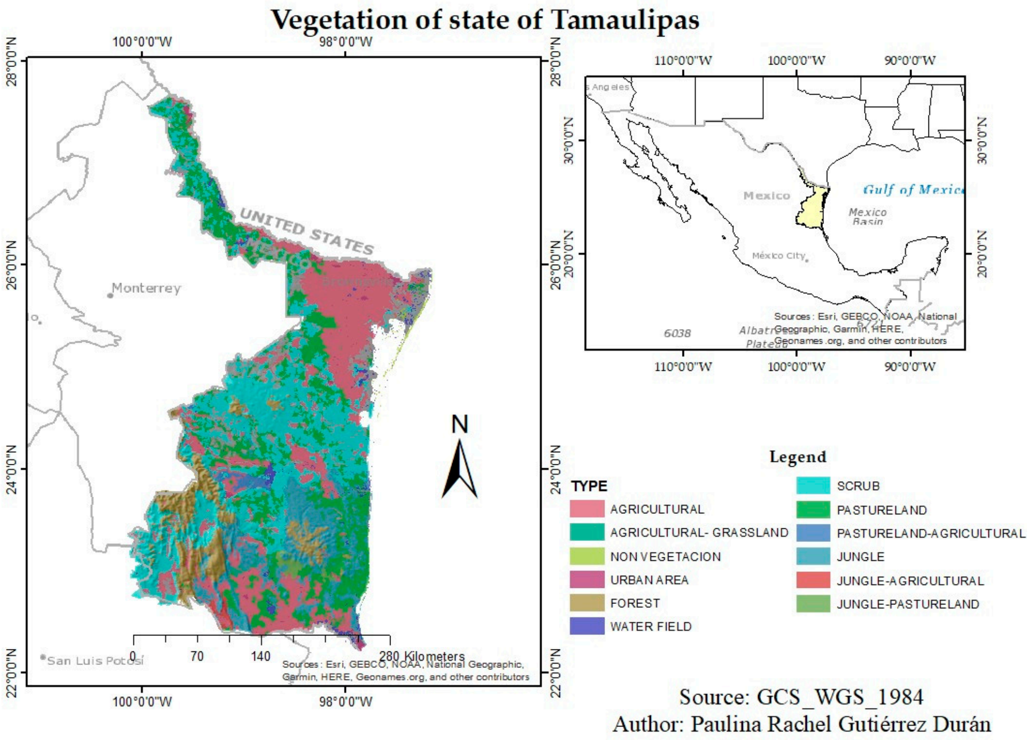

Figure 5. Location of the state of Tamaulipas and types of vegetation.

4. Conclusions

The Fabaceae family stands out not only for its remarkable ecological diversity and species richness but also for its significant importance in traditional medicine worldwide. The literature search conducted across multiple databases revealed that 19% of the Fabaceae species native to Tamaulipas have undergone phytochemical studies, identifying phenols, flavonoids, alkaloids, tannins, and terpenoids, among other compounds. These metabolites are associated with antimicrobial, antifungal, antidiabetic, antispasmodic, anti-inflammatory, and tumor-cytotoxic activities. However, only 13.3% of the species have documented traditional therapeutic uses, mainly for digestive disorders, dermatological conditions, and parasitic infections.

The widespread use of Fabaceae across different cultures for purposes related to human health highlights the need to deepen research on their pharmacological and phytochemical properties. Moreover, the careful selection of extraction and analytical methods for bioactive compounds, along with rigorous evaluation of their activity against various microorganisms, is essential to scientifically validate their therapeutic potential and to promote their incorporation into modern medicine.

The integration of traditional knowledge with updated scientific research strengthens the importance of the Fabaceae family as a valuable source for the development of new treatments and natural products, reinforcing its relevance as a biological and cultural resource at a global level.

Conflicts of Interest: The authors declare no conflict of interest.

Author Contributions: P.R. G.—D. Conceptualization; P.R. G.—D., H.B. B-G. Investigation; H.B. B-G. Antimicrobial Activity, J.V. H-V Validation; F.E. O-S and J.E.-G. review and editing. P.R. G.—D. Writing—original; H.B. B-G. Formal analysis. All authors have read and agreed to the published. All authors have read and agreed to the published version of the manuscript.

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