A SYSTEMATIC REVIEW ON SECONDARY METABOLITES OF GENUS *SOPHORA*: CHEMICAL DIVERSITY

*AMAURY FARIAS [a] AND PATRICIO ITURRIAGA [b]**

[a]*Doctorado en Ciencias de Recursos Naturales, Facultad de Ingeniería y Ciencias, Universidad de La Frontera, Temuco, Chile.*
[b]*Laboratorio de Síntesis Orgánica y Farmacología Molecular, Universidad de La Frontera, Temuco, Chile.*

ABSTRACT

The genus *Sophora* (Fabaceae) has been used by different cultures for medicinal and ceremonial reasons. This has led to describe and isolate the compounds present in the different parts of different species. In this review, we surveyed the secondary metabolites present in 20 different species of *Sophora*, which have been identified, isolated, and purified between 1969 and 2020. The aims of this review are demonstrate the spatial temporal evolution of research in the identification of secondary metabolites in the genus *Sophora* and determine the secondary metabolites identified and classified in the different species of the genus *Sophora* which may serve as a potential guide for future research. The countries with the highest number of species studied are China, South Korea, and the United States of America. The species that presented a greater identification of compounds are *S. alopecuroides*, *S. secundiflora*, *S. tonkinensis* and *S. flaveceses*, presenting a wide variety of compounds such as alkaloids, flavonoids, flavones, flavanones, chalcones, among others. The most studied plant parts in research are the roots, seed, and leaves, but in some species only one part was studied, leaving the possibility of studying the rest of the plant. And the difference in the presence of compounds in species that are present in different geographic positions should be considered for future studies.

Keywords: *Sophora*, secondary metabolites, alkaloids, flavonoids, flavanones, isoflavonoids, chalcones.

1. INTRODUCTION

The genus *Sophora* belongs to the family Fabaceae, consisting of about 52 species distributed in America, Asia, Africa, and Oceania [1], [2]. They have been used for different uses in traditional culture and medicine [3], [4], [5], [6], [7], [8], [9], [10], [11], [12]. In Pakistan the *Sophora mollis* is used as diuretic [6], anti-fungal [6], antibacterial [4], [6], [8]. In Nepal, *Sophora mollis* is used to treat rheumatism and cold [9]. Natives of the southern United States and Mexico used the mescalbean (seed of *Sophora secundiflora*) in rites where they experienced visions and hallucinations [13]. For this reason, it has been sought, described and purified different compounds in different species, such as *S. alopecuroides* [10], [11], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], *S. arizonica* [25], *S. davidii* [25], [26], *S. exigua* [28], [29], [30], *S. flavescens* [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], *S. fraseri* [50], *S. gypsophila* [25], *S. japonica* [31], [49], [51], [52], [53], [54], [55], [56], [57], *S. jaubertii* [58], *S. koreensis* [59], *S. leachiana* [60], [61], *S. mollis* [9], [62], *S. moorcroftiana* [63], *S. prostrata* [64], *S. secundiflora* [3], [13], [25], [65], [66], [67], [68], [69], [70], [71], [72], [73], [74], [75], *S. tetraptera* [76], *S. tomentosa* [77], [78], *S. tonkinensis* [31], [79], [80], [81], [82], [83], [84], [85], [86], [87], *S. velutina* [88] and *S. viciifolia* [89], [90].

Among these species they have described compounds such as alkaloids, flavonoids, flavonols, isoflavonoids, isoflavanones, chromones, and other [91], [92], [93]. Alkaloids mostly identified among species are cytisine [3], [18], [58], [66], [68], [70], [75], [89], anagyrine [13], [18], [28], [33], [58], [65], [66], [70], [75], lupanine [28], [49], [58], [65], [66], [69], [75], [89] and matrine [9], [14], [15], [16], [18], [23], [33], [49], [58], [85], [86], [89], [90]. While shikimic acid derivatives are a diversity of compounds such as genistein [25], [31], [56], [63], [67], [87], [94], quercetin [31], [52], [56], [90], rutin [9], [31], [52], [56] and kurarinone [11], [31], [35], [37], [40], [42], [44], [47] and others with similar structure between them, such as secundiflorol A-I [25], [67], [74], kurosol A-C [24] or alopecurone A-O [10], [11], [21]. Which have been obtained from different parts of the plant such as leaves [52], [62], [65], [70], stems [25], [62], [65], [88], roots [25], [79], [87], [95], seeds [13], [24], [51], [58] and even flowers [56], [57], [90]. Many of the identified and purified compounds have been used in the search for new drugs thanks to the biological activity [93]. Some compounds have exhibited antibacterial [10], [62], anti-inflammatory [19], [53], neurological [34], [51], antioxidant [38], [62], [96] and miscellaneous [36], [45], [51], [97] activities.

The present paper reports a systematic analysis of the identified secondary metabolites present in the genus *Sophora*, which have been published in the lapse between 1969-2020. The search was conducted in different databases for a total of 86 articles in which the compounds were identified from parts of the different species studied. The current work aims to (i) demonstrate the spatial temporal evolution of research in the identification of secondary metabolites in the genus *Sophora*; (ii) determine the secondary metabolites identified and classified in the different species of the genus *Sophora* which may serve as a potential guide for future research. The keywords used for the search in the databases were "Sophora, natural products, secondary metabolites, isolated, natural compounds". The present exploratory study opens opportunities for further thematic, disciplinary, methodological, spatial, and temporal analysis. Furthermore, to generating an idea of what happens to the study of natural products in the genus *Sophora*.

2. MATERIALS AND METHODS

2.1 Database Search

The database of the secondary metabolites present in the genus *Sophora* was generated from the search for publications in different platforms, search engines, journals, and databases (Scopus, PubMed, ScienceDirect, Springer Link and Google Scholar). The keywords used to identify relevant publications in the fields of title, abstract and keywords (per publication): Sophora, natural products, secondary metabolites, isolated and natural compounds. Words and their combinations used to retrieve bibliographic records yielded about 500 publications. Subsequently, the documents were filtered, selecting only the articles, and discarding reviews, book chapters and books, obtaining around 250 articles approximately. Those 250 documents were filtered in those that developed the research of plant extracts and their compounds, giving us a total of 102 articles. Finally, these articles were reviewed and discarded those who spoke of secondary metabolites from plants of the genus *Sophora*, but were purchased from distributors of chemical compounds, giving us a total of 86 articles, covering the period of 1969-2020.

2.2 Construction and analysis of the database

The selected articles were entered to a Microsoft Excel spreadsheet, classifying the information under the criteria of 'author', 'Country author', 'Year of publication', 'Journal', 'Species', ´Country of the plant', 'Secondary metabolite' and 'Type of metabolite'.

Once the database is built, data were analyzed using RStudio version 1.1.456 (RStudio, PBC (https://www.rstudio.com/) and Microsoft Excel 365 (https://www.office.com/). The software RStudio was specifically developed for data science, statistics, and graphics, through different libraries that help to order, classify, and graph our database, for further analysis.

The database was supplemented in the types of compounds, searching for the compounds described in the PubChem database (https://pubchem.ncbi.nlm.nih.gov/), adding, corroborating or updating the information obtained from the articles.

**Corresponding author email: patricio.iturriaga@ufrontera.cl*

For the scope of the paper were prepare choropleth, barplot, and tables were prepared for the analysis of data related to the journal, its impact, main author, country of the author, species studied, country of the species, its parts studied and the purified compounds.

3. RESULTS

3.1 Publication Trends: Countries, Journal, Year of publication

Once entered the 86 articles to the Excel spreadsheet, a data analysis was made regarding the variables: author, journal, country of the main author and year of publication. The analysis of the journals was performed based on the number of articles published in them and their highest quartile (Q), in addition, which categories are within said quartile. The articles were published in 54 different journals, 15 of them in Q1, 12 in Q2 and 27 between Q3 and Q4. The journal with the most publications is Phytochemistry (*n=17, Q1*), followed by Journal of Natural Products (*n=6, Q1*) and in third place we find Phytotherapy Research (*n=4, Q1*) and Chemistry Letters (*n=4, Q2*), as shown in table 1.

Table 1. Journals in which secondary metabolites were published.

Journal	Number of publications	Highest Quartile	Category
Phytochemistry	17	Q1	Plant Science
Journal of Natural Products	6	Q1	Plant Science
Bioorganic & Medicinal Chemistry Letters	4	Q2	Organic Chemistry
Phytotherapy Research	4	Q1	Medicinal Chemistry; Pharmacology & Pharmacy
Life Sciences	3	Q2	Pharmacology & Pharmacy; Biology; Medicine, Research & Experimental
Molecules	3	Q2	Biochemistry & Molecular Biology; Multidisciplinary Chemistry
Phytomedicine	2	Q1	Plant Sciences; Medicinal Chemistry; Pharmacology & Pharmacy, Integrative & Complementary Medicine
ACS Medicinal Chemistry Letters	1	Q2	Medicinal Chemistry
Annual Review of Plant Biology	1	Q1	Plant Science
Annual Review of Pharmacology and Toxicology	1	Q1	Pharmacology & Pharmacy; Toxicology
Archives of Oral Biology	1	Q2	Dentistry, Oral Surgery & Medicine
Archives of Pharmacal Research	1	Q2	Medicinal Chemistry; Pharmacology & Pharmacy
Biochemical Pharmacology	1	Q1	Pharmacology & Pharmacy
Biomedical Dermatology	1	Q1	Dermatology
Bioorganic & Medicinal Chemistry	1	Q2	Medical Chemistry; Organic Chemistry
Environmental Toxicology and Pharmacology	1	Q2	Pharmacology & Pharmacy; Toxicology; Environmental Sciences
European Food Research and Technology	1	Q2	Food Science
Food and Chemical Toxicology	1	Q2	Toxicology; Food Science
Food Chemistry	1	Q1	Applied Chemistry; Food Science; Nutrition & Dietetics
Frontiers in Pharmacology	1	Q1	Pharmacology & Pharmacy
International Immunopharmacology	1	Q1	Pharmacology & Pharmacy
Journal of Enzyme Inhibition and Medicinal Chemistry	1	Q1	Biochemistry & Molecular Biology; Medicinal Chemistry
Journal of Pharmaceutical Sciences	1	Q1	Multidisciplinary Chemistry
Planta Medica	1	Q1	Integrative & Complementary Medicine
PloS One	1	Q2	Multidisciplinary Sciences
Science	1	Q1	Multidisciplinary Sciences
Tetrahedron Letters	1	Q2	Organic Chemistry
Others	27	Q3 or Q4	Plant Science; Medicinal Chemistry; Pharmacology & Pharmacy; Organic Chemistry; and other

The country of affiliation of the first author was analyzed in the selected articles, giving China (24) as the country with the highest number of authors, followed by South Korea (*n=20*), Japan (*n=18*), United States (*n=6*), Mexico (*n=4*) , Taiwan (*n=3*), Pakistan (*n=2*), Iran (*n=2*), Egypt (*n=1*), Nepal (*n=1*), Puerto Rico (*n=1*), Saudi Arabia (*n=1*), South Africa (*n=1*), Thailand (*n=1*) and Turkey (*n=1*).

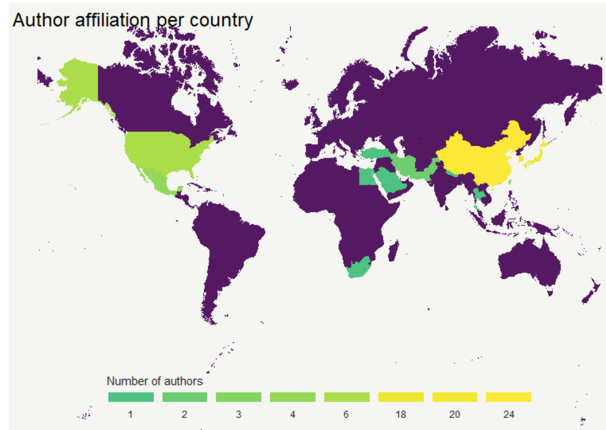
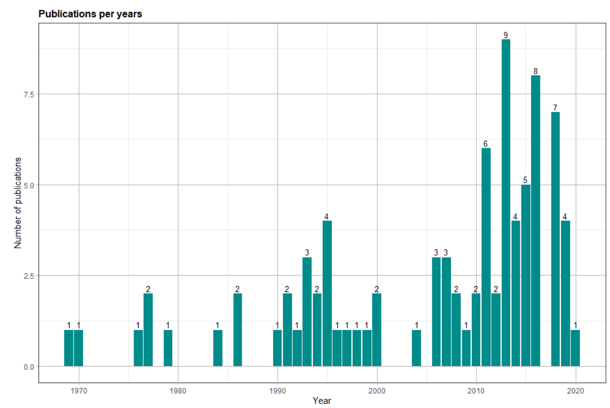


Figure 1. Choropleth map of the main author is country. The intensity of the colour indicates the country related to the affiliation of the main author.

Between 1969 and 2020 there are the analyzed articles, where most of the articles were published between 2010 and 2020, accounting for 55.8% of publications. The years in which the most articles were published are: 2013 (*n=9*), 2016 (*n=8*) and 2018 (*n=7*).



Graphic 1. Number of articles per year.

3.2 The species, parts studied, and compounds identified.

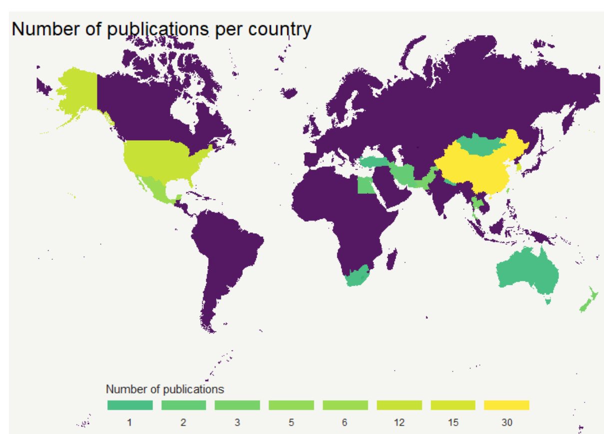
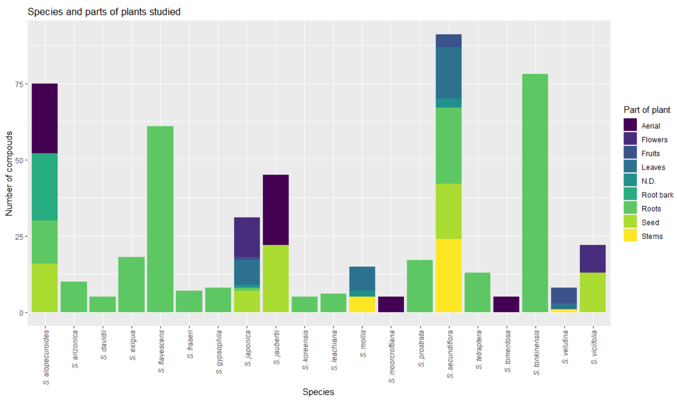


Figure 2. Number of publications per country. The intensity of the colour indicates the number of publications of various species by country.

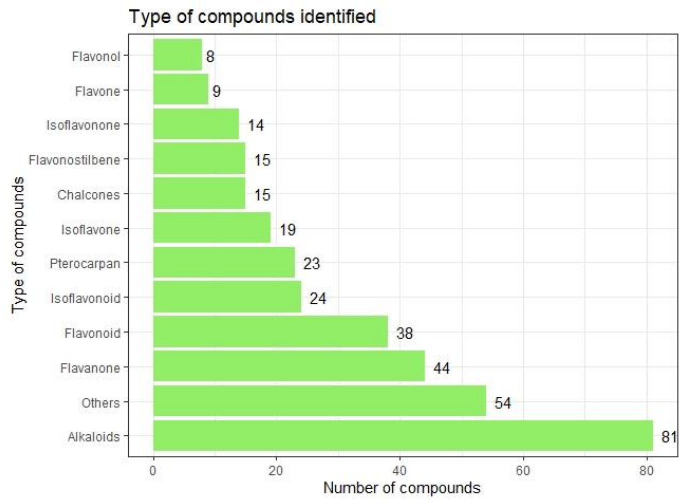
20 different species of *Sophora* were studied: *S. alopecuroides*, *S. arizonica*, *S. davidii*, *S. exigua*, *S. flavescens*, *S. fraseri*, *S. gypsophila*, *S. japonica*, *S. jaubertii*, *S. koreensis*, *S. leachiana*, *S. mollis*, *S. moorcroftiana*, *S. prostrata*, *S. secundiflora*, *S. tetraptera*, *S. tormentosa*, *S. tonkinensis*, *S. velutina*, and *S. viciiflora*. While the parts studied were roots, leaves, flowers, seeds, stems, aerial parts, root barks and in three cases we find ourselves we find no information.



Graphic 2. Species and parts of plants studied and relation of the number of compounds identified by part of the plant studied.

The most studied part in different species were the roots in 14 species, following by seed and leaves (graphic 2). According to the publications analyzed, the species with the most compounds described are *S. secundiflora* (*n=90*), *S. tonkinensis* (*n=78*), *S. alopecuroides* (*n=75*) and *S. flavescens* (*n=61*). In *S. alopecuroides* and *S. flavescens*, the identified compounds come from studies carried out only on roots, like most, as can be seen in the graphic 2.

The compounds discovered, identified, and analyzed. Different groups of flavonoids are also observed, such as flavones, flavanones, flavonols, isoflavonoids, among others. Most of the compounds described are alkaloids, including cytisine and matrine, together with their derivatives, as the main alkaloids. Second are flavanones and third are flavonoids. In the "others" we find xanthones, phenolic acids and other secondary metabolites in smaller quantities (graphic 3).



Graphic 3. Number of compounds described in the articles according to their categorization.

Table 2. Alkaloids identified in different species of Sophora.

Secondary metabolite	**Species**	**Reference**
(-)-12-Cytisineacetamide	*S. exigua*	[28]
(-)-12-Hydroxycytisine	*S. exigua*	[28]
(-)-12β-Hydroxyoxysophocarpine	*S. tonkinensis*	[86]
(-)-12β-Hydroxysophocarpine	*S. tonkinensis, S. viciifolia*	[86], [89]
(-)-13,14-Dehydrosophoridine	*S. flavescens*	[33]
(-)-14β-Hydroxymatrine	*S. tonkinensis, S. viciifolia*	[86], [89]
(-)-14β-Hydroxyoxymatrine	*S. tonkinensis*	[86]
(-)-14β-Hydroxysophoridine	*S. viciifolia*	[89]
(-)-5,6-Dehydrolupanine	*S. viciifolia*	[89]
(-)-5α-Hydroxysophocarpine	*S. tonkinensis*	[86]
(-)-9α-Hydroxysophocarpine	*S. flavescens, S. tonkinensis, S. viciifolia*	[33], [86], [89]
(-)-Crystine	*S. tonkinensis*	[85]
(-)-Lupanine	*S. exigua*	[28]
(-)-N-Acetylcytisine	*S. secundiflora*	[70]
(-)-N-Formylcytisine	*S. exigua, S. secundiflora*	[28], [70]
(-)-N-Methylcytisine	*S. exigua, S. secundiflora*	[28], [70]
(+)-11-Oxocytisine	*S. secundiflora*	[70]
(+)-12α-Hydroxysophocarpine	*S. flavescens, S. tonkinensis*	[33], [86]
(+)-5,6-Dehydrolupanine	*S. exigua*	[28]
(+)-5α-Hydroxylemannine	*S. tonkinensis*	[86]
(+)-5α-Hydroxymatrine	*S. tonkinensis*	[85]
(+)-5α-Hydroxyoxymatrine	*S. tonkinensis*	[85], [86]
(+)-5α-Hydroxyoxysophocarpine	*S. tonkinensis*	[86]
(+)-9α-Hydroxymatrine	*S. flavescens, S. tonkinensis, S. viciifolia*	[33], [86], [89]
(+)-Allomatrine	*S. flavescens*	[33]
(+)-Oxymatine	*S. flavescens*	[49]
(+)-Oxysophocarpine	*S. flavescens, S. tonkinensis*	[33], [86]
Δ5,6-Dehydrolupanine	*S. secundiflora*	[65]
Δ5-dehydrolupanine	*S. secundiflora*	[13]
11,12-Dehydrosparteine	*S. alopecuroides*	[18]
11-Allylcytisine	*S. secundiflora*	[69]
12β-Hydroxysophocarpine	*S. alopecuroides, S. jaubertii*	[15], [18], [58]
14β-Hydroxymatrine	*S. alopecuroides, S. tonkinensis, S. jaubertii*	[15], [18], [58], [85]

14β-Hydroxyoxymatrine	*S. tonkinensis*	[85]
5,17-Dehydrimatrine	*S. alopecuroides, S. jaubertii*	[18], [58]
5,6-Dehydrolupanine	*S. alopecuroides, S. jaubertii, S. secundiflora*	[18], [58], [66], [71], [75]
5-Hydroxylupanine	*S. flavescens*	[49]
5α,14β-Dihydroxymatrine	*S. tonkinensis*	[85]
6,7-Dihydroxylupanine	*S. velutina*	[88]
7,11-Dehydromatrine	*S. alopecuroides, S. jaubertii*	[18], [58]
7-Hydroxylupanine	*S. flavescens, S. velutina*	[49], [88]
7α-Hydroxysophoramine	*S. alopecuroides*	[15]
7β-Sophoramine	*S. tonkinensis*	[85]
Adenocarpine	*S. alopecuroides, S. jaubertii*	[15], [58]
Ammodendrine	*S. secundiflora*	[66], [75]
Anagyrine	*S. exigua, S. flavescens, S. jaubertii, S. secundiflora, S. tonkinensis*	[13], [18], [28], [33], [58], [65], [66], [68], [70], [71], [75], [85]
Baptifoline	*S. alopecuroides, S. exigua, S. jaubertii, S. secundiflora*	[15], [18], [28], [58], [70]
Cytisine	*S. alopecuroides, S. exigua, S. jaubertii, S. secundiflora, S. velutina, S. viciifolia*	[3], [13], [18], [28], [58], [65], [66], [68], [70], [71], [75], [88], [89]
Epi-lupinine	*S. secundiflora*	[13]
Isosophoramine	*S. jaubertii*	[58]
Kushenine	*S. flavescens*	[49]
Lamprolobine	*S. jaubertii*	[58]
Lehmannine	*S. alopecuroides, S. flavescens, S. jaubertii*	[11], [18], [33], [58]
Lupanine	*S. flavescens, S. jaubertii, S. secundiflora, S. viciifolia*	[49], [58], [65], [66], [68], [69]
Lupinine	*S. secundiflora*	[66], [71], [75]
Matrine	*S. alopecuroides, S. flavescens, S. jaubertii, S. mollis, S. tonkinensis, S. viciifolia*	[14], [15], [16], [18], [33], [85]
N-acetoxyanagyrine	*S. secundiflora*	[66], [75]
N-Butylcitisine	*S. flavescens*	[49]
N-Formylcytisine	*S. secundiflora*	[65]
N-Methylcytisine	*S. alopecuroides, S. flavescens, S. jaubertii, S. secundiflora, S. velutina*	[3], [13], [18], [22], [58], [65], [66], [71], [75], [88]
N-methylenehydroxycytisine	*S. velutina*	[88]
Oxosparteine	*S. secundiflora*	[65]
Oxylupanine	*S. flavescens*	[49]
Oxymatrine	*S. alopecuroides, S. flavescens, S. japonica, S. jaubertii, S. tonkinensis, S. viciifolia*	[14], [18], [33], [34], [53], [54], [58], [85], [86], [89]
Rhombifoline	*S. secundiflora*	[65], [69]
Sophocarpine	*S. alopecuroides, S. flavescens, S. jaubertii, S. tonkinensis, S. viciifolia*	[15], [18], [23], [33], [58], [85], [86], [89], [90]
Sophocarpine-N-oxide	*S. alopecuroides, S. jaubertii, S. viciifolia*	[18], [58], [89]
Sophoramine	*S. alopecuroides, S. flavescens, S. jaubertii, S. tonkinensis*	[15], [18], [23], [58], [86]
Sophoranol	*S. alopecuroides, S. jaubertii, S. tonkinensis*	[18], [58], [86]
Sophoranol-N-oxide	*S. alopecuroides, S. jaubertii*	[18], [58]
Sophorcarpine	*S. jaubertii*	[58]
Sophoridine	*S. alopecuroides, S. jaubertii, S. viciifolia*	[14], [15], [18], [58], [89]
Sophoridine-N-oxide	*S. alopecuroides, S. jaubertii*	[18], [58]
Sparteine	*S. secundiflora*	[13], [65], [66], [71], [75]
Termopsine	*S. secundiflora*	[68]
Thermopsine	*S. tonkinensis, S. velutina*	[85], [88]
Unidentified (230 m/z)	*S. secundiflora*	[66], [75]
Unidentified (244 m/z)	*S. secundiflora*	[66], [75]
Velutinine	*S. velutina*	[88]
α-Isosparteine	*S. alopecuroides*	[18]
β-isosparteine	*S. secundiflora*	[69]

Table 3. Flavanones identified in different species of Sophora.

Secondary metabolite	**Species**	**Reference**
(2S)-7,4'-Dihydroxy-5-methoxy-8-(γ,γ-dimethylallyl)-flavanone	*S. flavescens*	[40]
2'-Demethoxyleachianone B	*S. alopecuroides*	[11]
2'-*O*-Methylsophoraflavone K	*S. alopecuroides*	[11]
3,7,4'-Trihydroxy-5-methoxy-8-prenylflavanone	*S. flavescens*	[44]
3-Hydroxyglabrol	*S. prostata*	[64]
5,4'-Di-*O*-methylsophoraflavanone G	*S. alopecuroides*	[11]
5,7,2'-Trihydroxy-8-lavandulylflavanone	*S. alopecuroides*	[10]
6,8-Diprenul-2',4',7'-trihydroxyflavanone	*S. tonkinensis*	[87]
7,4'-Dihydroxy-6,8-diprenylflavanone	*S. tonkinensis*	[80]

8-Prenylnaringenin	*S. alopecuroides, S. flavescens*	[11], [45]
Alopecurone G	*S. alopecuroides*	[11], [21]
Echinoisoflavanone	*S. koreensis*	[59]
Euchrenone a_9	*S. tetraptera*	[76]
Exiguaflavanone A	*S. exigua*	[30]
Exiguaflavanone B	*S. exigua*	[30]
Exiguaflavanone C	*S. exigua*	[29]
Exiguaflavanone D	*S. exigua*	[29]
Exiguaflavanone E	*S. exigua*	[29]
Exiguaflavanone F	*S. exigua*	[29]
Flemichin	*S. tonkinensis*	[87]
Isosakuranin	*S. viciifolia*	[90]
Japonicasin A	*S. japonica*	[96]
Japonicasin B	*S. japonica*	[96]
Kushenol	*S. flavescens*	[31]
Kushenol A	*S. flavescens*	[37], [45]
Kushenol C	*S. flavescens*	[45]
Kushenol I	*S. flavescens*	[45]
Kushenol M	*S. flavescens*	[42]
Kushenol N	*S. flavescens*	[42], [44]
Kushenol T	*S. flavescens*	[37], [47]
Leachianone A	*S. alopecuroides, S. davidii, S. flavescens*	[11], [26], [37], [44]
Leachianone B	*S. davidii*	[26]
Leachianone F	*S. leachiana*	[60]
Leachianone G	*S. leachiana*	[60]
Liquiritigenin	*S. gypsophila*	[25]
Neoliquiritin	*S. alopecuroides*	[24]
Norkurarinol	*S. flavescens*	[47]
Norkurarinone	*S. flavescens*	[47]
Prostratol F	*S. prostrata*	[64]
Prostratol G	*S. prostrata*	[64]
Sophoraflavanone G	*S. alopecuroides, S. exigua, S. flavescens*	[11], [19], [20], [30], [32], [35], [36], [37], [42], [43], [44], [48]
Sophoraisoflavanone A	*S. fraseri, S. tomentosa*	[50], [77]
Sophoranochromene	*S. tonkinensis*	[87]

Table 4. Flavonoids identified in different species of Sophora.

Secondary metabolite	Species	Reference
(2R)-3α,7,4'-Trihydroxy-5-methoxy-8-(γ,γ-dimethylallyl)-flavanone	*S. flavescens*	[47]
(2S)-2'-Methoxykurarinone	*S. flavescens*	[37], [42], [47]
2,3-dihydro-7-hydroxy-2-[2,4-dihydroxy-3-(3-methyl-2-buten-1-yl)phenyl]-8-(3-methyl-2-buten-1-yl)-4H-1-benzopyran-4-one, named 20-hydroxyglabrol.	*S. tonkinensis*	[87]
2'-Methoxykurarinone	*S. flavescens*	[44]
6- γ,γ-Dimethylallyl-5,7,3',4',-tetrahydroxyflavanone	*S. secundiflora*	[67]
8-Lavandulylkaempferol	*S. flavescens*	[42]
8-Prenylkaempferol	*S. flavescens*	[45], [97]
Calycosin	*S. flavescens, S. fraseri, S. secundiflora*	[35], [50], [67], [74]
Cladrin	*S. secundiflora*	[67]
Diosmetin	*S. moorcroftiana*	[63]
Farnisin	*S. moorcroftiana*	[63]
Glabrol	*S. tonkinensis, S. prostrata*	[64], [87]
Isobavachin	*S. alopecuroides*	[11]
Isorhamnetin-3-*O*-β-D-rutinoside	*S. japonica*	[57]
Kurarinol	*S. flavescens*	[37], [42]
Kurarinone	*S. alopecuroides, S. flavescens*	[11], [31], [35], [37], [40], [42], [44], [47]
Kushecarpin D	*S. flavescens*	[46]
Lupinifolin	*S. tonkinensis*	[79]
Narcissin	*S. japonica*	[56]
Orobol	*S. japonica, S. secundiflora*	[25], [56]
Pseudobaptigenin	*S. secundiflora*	[74]

Quercetin	*S. japonica, S. viciifolia*	[31], [52], [56], [90]
Rutin	*S. mollis, S. japonica*	[9], [31], [51], [52], [56]
Sophoraclin	*S. tonkinensis*	[31]
Sophoraflavonoloside	*S. japonica*	[51]
Sophoranone	*S. tonkinensis*	[31]
Sophoratonin A	*S. tonkinensis*	[79]
Sophoratonin B	*S. tonkinensis*	[79]
Sophoratonin C	*S. tonkinensis*	[79]
Sophoratonin D	*S. tonkinensis*	[79]
Sophoratonin E	*S. tonkinensis*	[79]
Sophoratonin F	*S. tonkinensis*	[79]
Sophoratonin G	*S. tonkinensis*	[79]
Sophoratonin H	*S. tonkinensis*	[79]
Tamarixetin	*S. japonica*	[52], [56]
Tricin-7-*O*-β-D-glucopyranoside	*S. viciifolia*	[90]
Trifolirhizin	*S. alopecuroides, S. flavescens, S. tonkinensis*	[11], [35], [40], [42], [87]
Troxerutin	*S. japonica*	[55]

Table 5. Flavonols identified in different species of Sophora.

Secondary metabolite	**Species**	**Reference**
8-Lavandulyl-5,7,4'-trihydroxy-flavonol	*S. flavescens*	[35]
Desmethylanhydroicaritin	*S. flavescens*	[41]
Kaempferol	*S. japonica*	[31], [56]
Kaempferol 3-O-α–L-rhamnopyranosyl(1→6)β-D-glucopyranosyl(1→2)β-D-glucopyranoside	*S. japonica*	[51]
Kaempferol-3-rutinoside	*S. japonica*	[57]
Noranhydroicaritin	*S. flavescens*	[35]
Sophoflavescenol	*S. flavescens*	[38], [39]
Tonkinensisol	*S. tonkinensis*	[82]

Table 6. Flavonostilbenes identified in different species of Sophora.

Secondary metabolite	**Species**	**Reference**
Alopecurone A	*S. alopecuroides*	[21]
Alopecurone B	*S. alopecuroides*	[11], [21]
Alopecurone C	*S. alopecuroides*	[11], [21]
Alopecurone D	*S. alopecuroides*	[21]
Alopecurone E	*S. alopecuroides*	[21]
Alopecurone F	*S. alopecuroides*	[11], [21]
Alopecurone H	*S. alopecuroides*	[10]
Alopecurone I	*S. alopecuroides*	[10]
Alopecurone J	*S. alopecuroides*	[10]
Alopecurone K	*S. alopecuroides*	[10]
Alopecurone L	*S. alopecuroides*	[10]
Alopecurone M	*S. alopecuroides*	[11]
Alopecurone N	*S. alopecuroides*	[11]
Alopecurone O	*S. alopecuroides*	[11]
Leachianone I	*S. leachiana*	[61]

Table 7. Isoflavanones identified in different species of Sophora.

Secondary metabolite	**Species**	**Reference**
Cajanone	*S. tetraptera*	[76]
Fraserinone A	*S. fraseri*	[50]
Kenusanone A	*S. koreensis, S. tetraptera*	[59],[76]
Lespedeol B	*S. tetraptera*	[76]
Prostratol A	*S. prostrata*	[95]
Prostratol B	*S. prostrata*	[95]

Prostratol C	*S. prostrata*	[95]
Prostratol D	*S. prostrata*	[64]
Prostratol E	*S. prostrata*	[64]
Tetrapterol A	*S. tetraptera*	[76]
Tetrapterol C	*S. tetraptera*	[76]
Tetrapterol D	*S. tetraptera*	[76]
Tetrapterol E	*S. tetraptera*	[76]
Unaniisoflavan	*S. gypsophila*	[25]

Table 8. Isoflavones identified in different species of Sophora.

Secondary metabolite	Species	Reference
Alpinumisoflavone	*S. moorcroftiana*	[63]
Biochanin A	*S. secundiflora*	[25]
Daidzein	*S. flavescens*	[40]
Derrone	*S. arizonica*	[25]
Erythrinin B	*S. tomentosa*	[77]
Formononetin	*S. flavescens, S. secundiflora, S. tonkinensis*	[25], [31], [36], [40], [45], [47], [67], [74], [87]
Genistein	*S. japonica, S. moorcroftiana, S. secundiflora, S. tonkinensis*	[25], [31], [56], [63], [67], [87], [94]
Genistein 7,4'-di-O-b-D-glucopyransoide	*S. japonica*	[51]
Genistin	*S. japonica*	[51]
Kurosol A	*S. alopecuroides*	[24]
Kurosol B	*S. alopecuroides*	[24]
Kurosol C	*S. alopecuroides*	[24]
Lonchocarpol	*S. tonkinensis*	[79]
Lonchocarpol A	*S. tetraptera*	[76]
Pratensein	*S. japonica, S. moorcroftiana, S. secundiflora*	[56], [63], [67], [74]
Sissotrin	*S. japonica*	[52]
Sophoricoside	*S. japonica*	[51]
Unnamed 14	*S. arizonica, S. gypsophila*	[25]
Unnamed 15	*S. gypsophila*	[25]

Table 9. Isoflavonoids identified in different species of Sophora.

Secondary metabolite	Species	Reference
7-Methoxyebenosin	*S. tonkinensis*	[79]
Arizonicanol A	*S. arizonica, S. secundiflora*	[25]
Arizonicanol B	*S. arizonica*	[25]
Arizonicanol C	*S. arizonica, S. secundiflora*	[25]
Arizonicanol D	*S. arizonica*	[25]
Arizonicanol E	*S. arizonica*	[25]
Cajanin	*S. japonica*	[56]
Echinoisosophoranone	*S. koreensis*	[59]
Gancaonin B	*S. secundiflora*	[67]
Isoflavan	*S. secundiflora*	[25]
Prunetin	*S. secundiflora*	[25]
Secondifloran	*S. secundiflora*	[25]
Secundifloran	*S. secundiflora*	[67], [74]
Secundiflorol A	*S. secundiflora*	[25], [67], [74]
Secundiflorol B	*S. secundiflora*	[25], [67], [74]
Secundiflorol C	*S. secundiflora*	[25], [67], [74]
Secundiflorol D	*S. secundiflora*	[74]
Secundiflorol E	*S. secundiflora*	[74]
Secundiflorol F	*S. secundiflora*	[25], [74]
Secundiflorol G	*S. arizonica*	[25]
Secundiflorol H	*S. secundiflora*	[25]
Secundiflorol I	*S. gypsophila*	[25]
Sophorabioside	*S. japonica*	[51]
Sophoronol	*S. fraseri*	[50]

Table 10. Pterocarpans identified in different species of Sophora.

Secondary metabolite	**Species**	**Reference**
(-)-Maackiain	*S. alopecuroides, S. flavescens, S. tetraptera*	[40], [42], [76]
3-Methylmaackiapterocarpan B	*S. tonkinensis*	[87]
Dehydromaackiain	*S. tonkinensis*	[79]
Erybraedin D	*S. tonkinensis*	[79]
Erythrabyssin	*S. prostrata*	[64]
Ficifolinol	*S. prostrata*	[64]
Flemichapparin B	*S. tonkinensis*	[79]
l-Maackiain	*S. tomentosa*	[77]
Maackiain	*S. davidii, S. exigua, S. flavescens, S. fraseri, S. gypsophila, S. koreensis, S. prostrata, S. tonkinensis*	[25], [26], [29], [35], [50], [59], [64], [87]
Maackiain-3-O-glucoside 6''-acetate	*S. tonkinensis*	[87]
Maackiapterocarpan A	*S. tonkinensis*	[79]
Maackiapterocarpan B	*S. tonkinensis*	[81], [87]
Medicalpin	*S. gypsophila*	[25]
Medicapin	*S. secundiflora*	[67]
Medicarpan	*S. secundiflora*	[25]
Medicarpin	*S. flavescens, S. koreensis, S. tonkinensis*	[42], [59], [87]
Medicarpin-3-O-glucoside 6''-acetate	*S. tonkinensis*	[87]
Pterocarpin	*S. flavescens, S. tonkinensis*	[40], [87]
Sophoracarpan	*S. flavescens*	[42]
Sophoracarpan A	*S. tomentosa*	[77], [78]
Sophoracarpan B	*S. fraseri, S. tomentosa*	[50], [77], [78]
Tetrapterol B	*S. tetraptera*	[76]
Variabilin	*S. flavescens*	[42]

Table 11. Flavones identified in different species of Sophora.

Secondary metabolite	**Species**	**Reference**
3',5,7-Trihydroxy-4'-methoxyflavone-3-O-α-L-rhamnopyranosyl (1-6)-β-D-glucopyranoside	*S. viciifolia*	[90]
4',7-Dihydroxyflavone	*S. tonkinensis*	[87]
8-O-Methylherbacetin-3-O-sophoroside	*S. viciifolia*	[90]
Apigenin	*S. davidii*	[26]
Bayin	*S. tonkinensis*	[82]
Geraldol	*S. secundiflora*	[74]
Luteolin	*S. viciifolia*	[90]
Saponarin	*S. viciifolia*	[90]
Vitexin	*S. tonkinensis*	[82]

Table 12. Chalcones identified in different species of Sophora.

Secondary metabolite	**Species**	**Reference**
4,2'-Dihydroxy-6'',6''-dimethylpyrano[2'',3'':4',3']-chalcone	*S. prostata*	[64]
Ammothamnidin	*S. alopecuroides*	[11]
Bavachalcone	*S. prostata*	[64]
Isobavachalcone	*S. prostate*	[64]
Isoliquiritigenin	*S. gypsophila, S. tonkinensis*	[25], [87]
Kuraridin	*S. flavescens*	[31], [40], [42], [44], [47]
Sophoradin	*S. tonkinensis*	[87]
Sophoradochromene	*S. tonkinensis*	[79]
Tonkinochromane A	*S. tonkinensis*	[33], [87]
Tonkinochromane B	*S. tonkinensis*	[33]
Tonkinochromane C	*S. tonkinensis*	[33]
Tonkinochromane D	*S. tonkinensis*	[33]
Tonkinochromane E	*S. tonkinensis*	[33]
Tonkinochromane F	*S. tonkinensis*	[33]

Table 13. Other compounds identified in different species of Sophora.

Secondary metabolite	Type of metabolite	Species	Reference
Bolusanthin IV	Arylbenzofuran	*S. tonkinensis*	[87]
2-(2,4-Dihydroxyphenyl)-5,6-methylenedioxybenxofuran	Benzofuran	*S. tonkinensis*	[87]
2-(2',4'-Dihydroxyphenyl)-5,6-methylenedioxybenzofuran	Benzofuran	*S. fraseri*	[50]
Ellagic acid 4-O-alpha-L-arabinofuranoside	Benzopyran	*S. japonica*	[52]
Homopterocarpin	Benzopyran	*S. tonkinensis*	[79]
Isoneorautenol	Benzopyran	*S. prostrata, S. tetraptera*	[64], [76]
Sophororicoside	Benzopyran	*S. viciifolia*	[90]
Methyl ferulate	Caffeic acid	*S. alopecuroides*	[24]
Compound #10	Caffeic acid ester mixture	*S. arizonica*	[25]
3-Methoxy-1-(3-methylbut-2-en-1-yl)-6a,12a-dihydro-6H-[1,3]dioxolo[4',5':5,6]benzofuro[3,2-c]chromen-2-ol	Chromone	*S. tonkinensis*	[87]
Exiguachromone A	Chromone	*S. exigua*	[29]
Leachianone H	Chromone	*S. leachiana*	[60]
6-(2,2-Dimethyl-4-chromanone)acrylic acid	Chromone	*S. alopecuroides*	[11]
Methyl-4-coumarate	Coumaric acid	*S. alopecuroides*	[24]
Maltol-3-O-(4'-O-cis-p-coumaroyl-6'-O-(3-hydroxy-3-methylglutaroyl))-ß-glucopyranoside	Coumaric acid	*S. japonica*	[57]
(+)-Wikstromol	Lignan	*S. alopecuroides*	[24]
indole or isoquinoline derivatives	Other	*S. secundiflora*	[72], [73]
Hopeaphenol	Phenol	*S. leachiana*	[61]
Gallic acid	Phenolic acid	*S. japonica, S. mollis*	[52], [62]
Caffeic acid octadecyl ester	Phenolic acid	*S. prostrata*	[64]
Caffiec acid	Phenolic acid	*S. mollis*	[62]
Chlorogenic acid	Phenolic acid	*S. mollis*	[62]
Ferrulic acid	Phenolic acid	*S. mollis*	[62]
m-Coumeric acid	Phenolic acid	*S. mollis*	[62]
p-Coumeric acid	Phenolic acid	*S. mollis*	[62]
Syringic acid	Phenolic acid	*S. mollis*	[62]
Vanillic acid	Phenolic acid	*S. mollis*	[62]
Methyl-3-(3',4'-dimethoxyphenyl)-2-propenoate	Phenyl	*S. velutina*	[88]
Pentacosanyl caffeate	Phenyl propanoid	*S. tetraptera*	[76]
Kudolignan A	Phenylpropanoid	*S. alopecuroides*	[24]
Kudolignan B	Phenylpropanoid	*S. alopecuroides*	[24]
4'-O-Methyl-8-prenylnaringenin	Pipecolic Acids	*S. secundiflora*	[68]
Aloperine	Piperidine	*S. alopecuroides*	[17]
Leachianol E	Polyphenol	*S. alopecuroides*	[11]
Pallidol	Polyphenol	*S. alopecuroides*	[11]
Davidiol D	Polyphenol	*S. davidii*	[27]
(-)-ε-Viniferin	Stilbene oligomer	*S. leachiana*	[61]
Lupeol	Triterpene	*S. tonkinensis*	[82]
12-Oleanene-3-one	Triterpene	*S. velutina*	[88]
Umbelliferone	Umbelliferone	*S. flavescens*	[40]
Isoxanthohumol	Xanthone	*S. flavescens*	[35], [37], [47]
5-Methylsophoraflavanone B	Xanthone	*S. flavescens*	[44]
Cudraxanthone D	Xanthone	*S. alopecuroides*	[11]

DISCUSSION

Among the 52 species in the genus *Sophora*, only 20 have been studied, the difficulty of study of the remaining 32 is the state of conservation of some of them, for example *Sophora toromiro* [98], listed in the category of 'Extinct in the Wild', or *Sophora rubriflora* [99], listed in the category of 'Critically Endangered' by the International Union for Conservation of Nature and Natural Resource® (IUCN, https://www.iucnredlist.org). In addition to the classification granted by the IUCN, there is the complexity of obtaining samples for the study, due to its geographical disposition, as occurs with the *Sophora saxicola* [100], located in Jamaica or *Sophora fernandeziana* [101], located in the Juan Fernandez archipelago in Chile.

In the search for scientific articles, a lot of them that mentioned secondary metabolites of a specific species was found, but when analyzing the article, the materials and methods mentioned that compound was bought pure from distributors or pharmaceutical companies, such as matrine [102] and oxymatrine [103], [104].

In the analysis of the different articles, it was observed that only part was studied, such as the roots in *S. koreensis* [59] or *S. gypsophila* [25]. New compounds could be identified and isolated from the different parts not studied of them. But this focus on the study of a single part may be due to the different species are classified according to their morphology in herb, shrub or tree [91], for example, *S. leachiana* is a species classified as herb [91], so it does not have a bark, so this par cannot be studied, but produces flowers and seeds, which could be studied. It has also been shown that the same species can produce compounds with difference in diversity and quantity, including the appearance or not of some of them [75].

CONCLUSIONS AND FUTURE PROSPECTIVE

Phytochemical studies of the compounds identified and isolated from the genus *Sophora* have increased in last 10 years, contemplating 55.8% of the total of the articles reviewed, showing an increasing interest in the knowledge of secondary metabolites in this genus. A 46.5% of the analyzed articles are published in journals with an impact of Q1. An 86.0% of the publications are made by authors affiliated with Asian research centers, the first positions are China, South Korea, and Japan, with 24, 20 and 18 publications, respectively. In the case of the studied species, of the 56 identified species, 20 of them were studied, the most important being *S. alopecuroides*, *S. secundiflora*, *S. tonkinensis* and *S. flavescens*. The most studied plant parts in research are the roots, seeds, and leaves. The major compounds identified are alkaloids, flavanones, flavonoids and isoflavonoids, but still are a lot of minor compounds corresponding to secondary metabolites.

The large number of unstudied species, together with the unstudied parts of the plants mentioned in the articles analyzed, allows new ideas and approaches to study of known and novel compounds. Also, the identification and differentiation of compounds present in species with presence in different geographical locations, either area, country, or continent.

COMPLEMENTARY MATERIAL

Table 14. Sophora species, parts studied and number of compounds of the parts.

Species	Part of the plant	Number of compounds
S. alopecuroides	Aerial	23
S. alopecuroides	Root bark	22
S. alopecuroides	Roots	14
S. alopecuroides	Seed	16
S. arizonica	Roots	10
S. davidii	Roots	5
S. exigua	Roots	18
S. flavescens	Roots	61
S. fraseri	Roots	7
S. gypsophila	Roots	8
S. japonica	Flowers	13
S. japonica	Fruits	1
S. japonica	Leaves	8
S. japonica	N.D.	1
S. japonica	Roots	1
S. japonica	Seed	7
S. jaubertii	Aerial	23
S. jaubertii	Seed	22
S. koreensis	Roots	5
S. leachiana	Roots	6
S. mollis	Leaves	8
S. mollis	N.D.	2
S. mollis	Stems	5
S. moorcroftiana	Aerial	5
S. prostrata	Roots	17
S. secundiflora	Fruits	4
S. secundiflora	Leaves	17
S. secundiflora	N.D.	3
S. secundiflora	Roots	25
S. secundiflora	Seed	18
S. secundiflora	Stems	24
S. tetraptera	Roots	13
S. tomentosa	Aerial	5
S. tonkinensis	Roots	78
S. velutina	Fruits	5
S. velutina	Leaves	2
S. velutina	Stems	1
S. viciifolia	Flowers	9
S. viciifolia	Seed	13

REFERENCES

1. *U.Quattrocchi. CRC World Dictionary of Medicinal and Poisonous Plants. Common Names, Scientific Names, Eponysm, Synonyms, and Eymology, Taylor & Francis Group, Boca Raton, 2012.*
2. M. Boozari, S. Soltani, M. Iranshahi, *Phyther Res.* **33**, 546, (2019).
3. J. L. Diaz, *Annu. Rev. Pharmacol. Toxicol.* **17**, 647 (1977).
4. Q. Abbas, S. W. Khan, S. Khatoon, S. A. Hussain, S. N. ul Hassan, A. Hussain, R. Qureshi, *J. Biodivers. Environ. Sci.* **5**, 75, (2014).
5. S. Farooq, A. Barki, M. Y. Khan, H. Fazal, *Pakistan J. Weed Sci. Res.* **18**, 277, (2012).
6. A. B. Gulshan, A. A. Dasti, S. Hussain, M. I. Atta, M. Amin, *ARPN J. Agric. Biol. Sci.* **7**, 750, (2012).
7. I. Hussain, A. Bano, F. Ullah, *Pakistan J. Bot.* **43**, 79, (2011).
8. N. Jabeen, M. Ajaib, M. F. Siddiqui, M. Ulfat, B. Khan, *FUUAST J. Biol.* **5**, 153, (2015).
9. R. Kunwar, C. Burlakoti, C. Chowdhary, R. Bussmann, *Med Aromat Plant Sci Biotechnol* **4**, 28, (2010).
10. C.X. Wan, J.G. Luo, X.P. Ren, L.-Y. Kong, *Phytochemistry* **116**, 290, (2015).
11. J. Kwon, S. Basnet, J. W. Lee, E.-K. Seo, N. Tsevegsuren, B. Y. Hwang, D. Lee, *Bioorg. Med. Chem. Lett.* **25**, 3314, (2015).
12. K. Khan, J. Alam, H. Ali, H. Ahmad, S. Muhammad, *Spec. J. Biol. Sci.* **3**, 16, (2017).
13. G. M. Hatfield, L. J. Valdes, W. J. Keller, W. L. Merrill, V. H. Jones, *Lloydia.* **40**, 374, (1977).
14. A. Chang, Z. Cai, Z. Wang, S. Sun, *African J. Tradit. Complement. Altern. Med.* **11**, 245, (2014).
15. Atta-ur-Rahman, M. I. Choudhary, K. Parvez, A. Ahmed, F. Akhtar, M. Nur-e-Alam, N. M. Hassan, *J. Nat. Prod.* **63**, 190, (2000).
16. B. Cai, N. Chen, J. Li, Z. Fang, G. Wang, X. Wang, X. Tan, T. Ban, Y. Lu, J. Med. *Plants Res.* **5**, 2682, (2011).
17. Z. Dang, L. Zhu, W. Lai, H. Bogerd, K.-H. Lee, L. Huang, C.-H. Chen, *ACS Med. Chem. Lett.* **7**, 240, (2016).
18. N. Goodarzi, E. Doorgard, P. Pournaghi, *Res. J. Pharmacogn.* **5**, 47, (2017).
19. C. Guo, L. Yang, C.-X. Wan, Y.-Z. Xia, C. Zhang, M.-H. Chen, Z.-D. Wang, Z.-R. Li, X.-M. Li, Y.-D. Geng, L.-Y. Kong, *Phytomedicine.* **23**, 1629, (2016).
20. C. Guo, L. Yang, J. Luo, C. Zhang, Y. Xia, T. Ma, L. Kong, *Int. Immunopharmacol.* **38**, 349, (2016).
21. M. Iinuma, M. Ohyama, T. Tanaka, *Phytochemistry*. **38**, 519, (1995).
22. Y.-F. Jiao, M. Lu, Y.-P. Zhao, N. Liu, Y.-T. Niu, Y. Niu, R. Zhou, J.-Q. Yu, *Molecules*. **23**, 510, (2018).
23. S. Kianbakht, R. Hajiaghaee, S. Akhondzadeh, *Phyther. Res.* **34**, 1108, (2020).
24. Z. J. Rong, G. S. Hu, S. Y. Lin, T. Yan, N. Li, Y. Zhao, J. M. Jia, A. H. Wang, *Molecules.* **25**, 2, (2020).
25. T. Tanaka, M. Ohyama, M. Iinuma, Y. Shirataki, M. Komatsu, B. Charles L., *Phytochemistry.* **48**, 1187, (1998).
26. Y. Huang, J. Hao, D. Tian, Y. Wen, P. Zhao, H. Chen, Y. Lv, X. Yang, *Front. Pharmacol.* **9**, 1, (2018).
27. M. Ohyama, M. Ichise, T. Tanaka, M. Iinuma, C. L. Burandt, *Tetrahedron Lett.*, **37**, 5155, (1996).
28. S. Takamatsu, K. Saito, S. Ohmiya, N. Ruangrungsi, I. Murakoshi, *Phytochemistry*. **30**, 3793, (1991).
29. M. Iinuma, J. Yokoyama, M. Ohyama, T. Tanaka, M. Mizuno, N. Ruangrungsi, *Phytochemistry.* **33**, 203, (1993).
30. N. Ruangrungsi, M. Iinuma, T. Tanaka, M. Ohyama, J. Yokoyama, M. Mizuno, *Phytochemistry*. **31**, 999, (1992).
31. Y. Cai, Q. Luo, M. Sun, H. Corke, *Life Sci.* **74**, 2157, (2004).
32. S.-M. Cha, J.-D. Cha, E.-J. Jang, G.-U. Kim, K.-Y. Lee, *Arch. Oral Biol.* **68**, 97, (2016).
33. P.-L. Ding, Z.-X. Liao, H. Huang, P. Zhou, D.-F. Chen, *Bioorg. Med. Chem. Lett.* **16**, 1231, (2006).
34. X.-H. Ge, L. Shao, G.-J. Zhu, *Metab. Brain Dis.* **33**, 1869, (2018).
35. Q. Huang, L. Xu, W.-S. Qu, Z.-H. Ye, W.-Y. Huang, L.-Y. Liu, J.-F. Lin, S. Li, H.-Y. Ma, *Eur. Food Res. Technol.* **243**, 1127, (2017).
36. W.-C. Huang, P.-Y. Gu, L.-W. Fang, Y.-L. Huang, C.-F. Lin, C.-J. Liou, *Phytomedicine*. **61**, 152852, (2019).
37. E. M. Hwang, Y. B. Ryu, H. Y. Kim, D.-G. Kim, S.-G. Hong, J. H. Lee, M. J. Curtis-Long, S. H. Jeong, J.-Y. Park, K. H. Park, *Bioorg. Med. Chem.* **16**, 6669, (2008).

38. H. A. Jung, S. E. Jin, R. J. Choi, H. T. Manh, Y. S. Kim, B.-S. Min, Y. K. Son, B. R. Ahn, B.-W. Kim, H. S. Sohn, J. S. Choi, *Arch. Pharm. Res.* **34**, 2087, (2011).
39. H. A. Jung, S. E. Jin, J.-S. Park, J. S. Choi, *Phyther. Res.* **25**, 709, (2011).
40. S. S. Kang, J. S. Kim, K. H. Son, H. W. Chang, H. P. Kim, *Fitoterapia*. **71**, 511, (2000).
41. C. W. Kang, N. H. Kim, H. A. Jung, H. W. Choi, M. J. Kang, J. S. Choi, G. Do Kim, *Environ. Toxicol. Pharmacol.* **43**, 140, (2016).
42. B. H. Kim, K. M. Na, I. Oh, I. H. Song, Y. S. Lee, J. Shin, T. Y. Kim, *Biochem. Pharmacol.* **85**, 1134, (2013).
43. C. S. Kim, S.-N. Park, S.-J. Ahn, Y.-W. Seo, Y.-J. Lee, Y. K. Lim, M. O. Freire, E. Cho, J.-K. Kook, *Anaerobe*. **19**, 17, (2013).
44. C. Y. Kim, H. J. Kim, K.-M. Kim, M.-H. Oak, *Biosci. Biotechnol. Biochem.* **77**, 395, (2013).
45. J. H. Kim, I. S. Cho, Y. K. So, H.-H. Kim, Y. H. Kim, J. *Enzyme Inhib. Med. Chem.* **33**, 1048, (2018).
46. L.-P. Pu, H.-P. Chen, M.-A. Cao, X.-L. Zhang, Q.-X. Gao, C.-S. Yuan, C.-M. Wang, *Life Sci*. **93**, 791, (2013).
47. T. H. Quang, N. T. T. Ngan, C. Van Minh, P. Van Kiem, B. H. Tai, N. X. Nhiem, N. P. Thao, B. T. T. Luyen, S. Y. Yang, Y. H. Kim, *Phyther. Res.* **27**, 1300, (2013).
48. Z.-Y. Wun, C.-F. Lin, W.-C. Huang, Y.-L. Huang, P.-Y. Xu, W.-T. Chang, S.-J. Wu, C.-J. Liou, *Food Chem. Toxicol.* **62**, 255, (2013).
49. S.-Y. Zhang, W. Li, H. Nie, M. Liao, B. Qiu, Y.-L. Yang, Y.-F. Chen, *Chem. Biodivers.* **15**, 1, (2018).
50. M. Iinuma, M. Ohyama, T. Tanaka, M. P. Hegarty, E. E. Egarty, *Phytochemistry*. **34**, 1654, (1993).
51. H. M. Abdallah, A. M. Al-Abd, G. F. Asaad, A. B. Abdel-Naim, A. M. El-halawany, *PLoS One*. **9**, 1, (2014).
52. M. I. S. Abdelhady, A. M. Kamal, S. M. Othman, M. S. Mubarak, T. Ben Hadda, *Med. Chem. Res.* **24**, 482, (2015).
53. X.-Q. Dong, Q. Du, W.-H. Yu, Z.-Y. Zhang, Q. Zhu, Z.-H. Che, F. Chen, H. Wang, J. Chen, *Iran. J. Pharm. Res.* **12**, 165, (2013).
54. D.-L. Fan, W.-J. Zhao, Y.-X. Wang, S.-Y. Han, S. Guo, *Int. J. Dermatol.* **51**, 463, (2012).
55. K. Kim, H. J. Cha, D. Joo, S. J. Choi, I. S. An, S. An, *Biomed. Dermatology*. **2**, 4, (2018).
56. Q. Chen, W. Zhang, W. Jin, I. Lee, B.-S. Min, H.-J. Jung, M. Na, S. Lee, K. Bae, *Planta Med.* **76**, 79, (2010).
57. W. Y. Yang, T. H. Won, C. H. Ahn, S. H. Lee, H. C. Yang, J. Shin, K. B. Oh, *Bioorganic Med. Chem. Lett.* **25**, 1394, (2015).
58. N. Küçükboyaci, N. Adigüzel, S. Özkan, F. Tosun, *Turkish J. Pharm. Sci*. **7**, 1, (2010).
59. M. Iinuma, M. Ohyama, T. Tanaka, M. Mizuno, S.-K. Hong, *Phytochemistry*. **30**, 3153, (1991).
60. M. Iinuma, M. Ohyama, T. Tanaka, F. A. Lang, *J. Nat. Prod.* **56**, 2212, (1993).
61. M. Iinuma, M. Ohyama, T. Tanana, F. A. Lang, *Phytochemistry.* **37**, 1157, (1994).
62. H. Iram, N. Rasool, M. Riaz, M. Zubair, U. Rashid, I. H. Bukhari, R. B. Tareen, M. S. Islam, *Asian J. Chem.* **25**, 10519, (2013).
63. S.-Y. Wang, Z.-L. Sun, T. Liu, S. Gibbons, W.-J. Zhang, M. Qing, *Phytother. Res.* **28**, 1071, (2014).
64. M. Iinuma, M. Ohyama, T. Tanaka, *Phytochemistry*. **38**, 539, (1995).
65. P. I. Chavez, G. Sullivan, *J. Nat. Prod.* **47**, 735, (1984).
66. R. García-Mateos, M. Soto-Hernández, F. Zavala-Chávez, G. Kite, *Agrociencia*. **41**, 161, (2007).
67. M. Iinuma, M. Ohyama, T. Tanaka, Y. Shirataki, C. L. Burandt, *Phytochemistry*. **39**, 907, (1995).
68. M. Izaddoost, B. G. Harris, R. W. Gracy, *J. Pharm. Sci.* **65**, 352, (1976).
69. W. J. Keller, M. Hatfield, *Phytochemistry*. **18**, 2068, (1979).
70. I. Murakoshi, H. Kubo, M. Ikram, M. Israr, N. Shafi, S. Ohmiya, H. Otomasu, *Phytochemistry.* **25**, 2000, (1986).
71. D. Pérez-Laínez, R. García-Mateos, R. San Miguel-Chávez, M. Soto-Hernández, E. Rodríguez-Pérez, G. Kite, *Zeitschrift für Naturforsch. C.* **63**, 653, (2008).
72. R. E. Schultes, *Science.* **163**, 245, (1969).
73. R. E. Schultes, *Annu. Rev. Plant Physiol.* **21**, 571, (1970).
74. Y. Shirataki, S. Yoshida, Y. Sugita, I. Yokoe, M. Komatsu, M. Ohyama, T. Tanaka, M. Iinuma, *Phytochemistry*. **44**, 715, (1997).
75. F. Zavala-Chávez, R. García-Mateos, M. Soto-Hernández, G. Kited, *Zeitschrift für Naturforsch. C.* **61**, 155, (2006).
76. M. Iinuma, M. Ohyama, Y. Kawasaka, T. Tanaka, *Phytochemistry.* **39**, 667, (1995).
77. T. Kinoshita, K. Ichinose, C. Takahashi, F.-C. Ho, J.-B. Wu, U. Sankawa, *Chem. Pharm. Bull.* **38**, 2756, (1990).
78. T. Kinoshita, K. Ichinose, C. Takahashi, U. Sankawa, *Chem. Pharm. Bull.* **34**, 3067, (1986).
79. J. Ahn, Y.-M. Kim, H.-S. Chae, Y. H. Choi, H.-C. Ahn, H. Yoo, M. Kang, J. Kim, Y.-W. Chin, *J. Nat. Prod.* **82**, 309, (2019).
80. H.-S. Chae, H. Yoo, Y.-M. Kim, Y. Choi, C. Lee, Y.-W. Chin, *Molecules.* **21**, 1049, (2016).
81. H.-S. Chae, H. Yoo, Y. H. Choi, W. J. Choi, Y.-W. Chin, *Biol. Pharm. Bull.* **39**, 259, (2016).
82. Y.-H. Deng, K.-P. Xu, Y.-J. Zhou, F.-S. Li, G.-Y. Zeng, G.-S. Tan, *J. Asian Nat. Prod. Res.* **9**, 45–, (2007).
83. P. Ding, D. Chen, *Helv. Chim. Acta*. **90**, 2236, (2007).
84. P. Ding, D. Chen, *Helv. Chim. Acta*. **89**, 103, (2006).
85. L. J. He, J. S. Liu, D. Luo, Y. R. Zheng, Y. B. Zhang, G. C. Wang, Y. L. Li, *Fitoterapia*. **139**, 104391, (2019).
86. Q.-M. Pan, Y.-H. Li, J. Hua, F.-P. Huang, H.-S. Wang, D. Liang, *J. Nat. Prod.* **78**, 1683, (2015).
87. H. Yoo, H.-S. Chae, Y.-M. Kim, M. Kang, K. H. Ryu, H. C. Ahn, K. D. Yoon, Y.-W. Chin, J. Kim, *Bioorg. Med. Chem. Lett.* **24**, 5644, (2014).
88. E. Korir, J. J. Kiplimo, N. R. Crouch, N. Moodley, N. A. Koorbanally, *Nat. Prod. Commun.* **7**, 1, (2012).
89. P. Xiao, H. Kubo, H. Komiya, K. Higashiyama, Y. Yan, J. Li, S. Ohmiya, *Phytochemistry*. **50**, 189, (1999).
90. Z. Tai, L. Cai, L. Dai, L. Dong, M. Wang, Y. Yang, Q. Cao, Z. Ding, *Food Chem.* **126**, 1648, (2011).
91. *I. W. Southon, F. A. Bisby, J. Buckingham, J. B. Harborne, J. L. Zarucchi International Legume Database and Information Service and CHCD and Chapman & Hall Database. Phytochemical dictionary of the Leguminosae, Chapman & Hall, London, 1994.*
92. P. M. Krishna, R. KNV, S. Srikant, D. Banji, *Rev. Bras. Farmacogn.* **22**, 1145, (2012).
93. S. H. Aly, A. M. Elissawy, O. A. Eldahshan, M. A. Elshanawany, T. Efferth, A. N. B. Singab, *Phytomedicine*. **64**, 153070, (2019).
94. S.-R. Jung, Y.-J. Kim, A.-R. Gwon, J. Lee, D.-G. Jo, T.-J. Jeon, J.-W. Hong, K.-M. Park, K. W. Park, *J. Med. Food*. **14**, 360, (2011).
95. M. Iinuma, M. Ohyama, T. Tanaka, *Phytochemistry*. **37**, 1713, (1994).
96. L.B. Zhang, J.L. Lv, H.L. Chen, *Fitoterapia*. **87**, 89, (2013).
97. W.F. Chiou, C.H. Lee, J.F. Liao, C.C. Chen, *Life Sci.* **88**, 335, (2011).
98. M. Rivera-Caniulao, C.B. Chaparro, *The IUCN Red List of Threatened Species*., (2021).
99. H. Chadburn, *IUCN Red List Threat. Species*. (2012).
100. D. L. Kelly, *IUCN Red List Threat. Species*. (1998).
101. World Conservation Monitoring Centre, *IUCN Red List Threat. Species*. (1998).
102. W. Haiyan, L. Yuxiang, D. Linglu, X. Tingting, H. Yinju, L. Hongyan, M. Lin, J. Yuanxu, W. Yanrong, Y. Jianqiang, *Pharm. Biol.* **51**, 844, (2013).
103. X. Y. Huang, C. X. Chen, *Phytomedicine*. **20**, 202, (2013).
104. M. Huang, Y.-Y. Hu, X.-Q. Dong, Q.-P. Xu, W.-H. Yu, Z.-Y. Zhang, *J. Ethnopharmacol.* **143**, 228, (2012).