Full Length Research Paper

**Jatropha dioica**, an Aztec plant with promising pharmacological properties: A systematic review

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Received 1 April, 2020; Accepted 10 June, 2020

Few pharmacological and toxicological studies have been conducted to demonstrate the usefulness and safety of using the *Jatropha dioica* extract. The aim of this study was to update the state of the art on the chemical composition, pharmacology, and toxicology of the species *J. dioica*, to find new possible applications. A search of different databases was carried out on the internet, specifically in Science Direct, PubMed, EBSCO, SCOPUS, Web of Science and Springer Link, with the keyword being “*Jatropha dioica*”. Despite the limited results with regard to the plant toxicity, it was shown that the extract to use is innocuous. In addition, it was found that *J. dioica* could be employed as an antioxidant, antibiotic, antifungal, or antiviral agent. Although promising, more scientific research is needed to further validate the ethno pharmacological use of the *J. dioica* extracts.

**Key words:** *Jatropha*, toxicity, chemical composition, ethno pharmacology, plants medicinal.

**INTRODUCTION**

The great biodiversity of medicinal plants in Mexico is an important source of remedies with an enormous cultural...
acceptance (Cirilo Aguilar et al., 2011). Although the use of medicinal plants was neglected for a long time, there is currently a great interest in their study due to their great therapeutic potential. That interest is focused today, essentially, on the pharmacological benefits derived from the consumption of the extracts from the fruits, seeds, vegetables, barks and roots. However, the lack of medicines and the adverse effects of many of them have made the use of medicinal plants and their extracts to play an important role for the treatment of ailments such as diabetes and cancer (Kim et al., 2013). Large number of plants belonging to the Euphorbiaceae family have been shown to have a number of medicinal benefits, industrial utility and applications in food (Sharma and Singh, 2012). Some authors have reported on the use of Jatropha species to produce biodiesel (Fresnedo-Ramirez and Orozco-Ramirez, 2013). In addition, it was reported that this species has important effects anticonvulsants, anticancer, hypoglycemic, hypotensive, anti-inflammatory, antimicrobial, and antioxidant (Kumar et al., 2016; Sharma and Singh, 2012).

Jatropha dioica Cerv. is a species of Jatropha with a succulent shrub, originally from Mexico but can also be found in Texas and Arizona (Aggie, 2010). The species is known for unusual names as “blood of the dragon”, “sangre de drago” (Govea-Salas et al., 2017), “Tlapecx Ptli” by the Aztecs (Domínguez et al., 1980) or “Sangregado”. The color appellative is due to the sap juice change the color when exposed to air from colorless to dark red. Its branches are reddish-brown with dark green leaves that are narrow in appearance. Its flowering period falls between April and May (Martinez et al., 2014).

Research of J. dioica can result in finding new bioactive compounds and provide new phytopharmaceutical drugs that can be used as therapeutic alternatives in some illness (Chandran et al., 2016). However, there is a little information available about the chemical composition, pharmacology and toxicology of this plant species.

The objective of this research was to update the state of the art on the chemical composition, pharmacology, and toxicology of the species J. dioica, to find new possible applications.

MATERIALS AND METHODS

Data acquisition

A search was carried out on different databases with Pub-Med, Web of Science, Science Direct, EBSCO, Scopus and Springer link using the descriptor “Jatropha dioica”. The literature search was carried out in English and Spanish from 1978 to 2018.

Final selection of the information

The search was performed concerning studies that were carried out on the plant J. dioica, selecting all those works that involved this plant in the investigation (Figure 1).

Data extraction

The selected articles were analyzed in order to systematize and facilitate the understanding of this plant studies. No article was rejected on the bases of methodological reasons.

RESULTS AND DISCUSSION

Publication related to J. dioica

Figure 2 shows the number of publication related to J. dioica found on the different databases. In SCOPUS, just nine articles were found. In Science Direct three research papers were found, repeats of the previous database. While in PubMed four works were obtained, all were repeats of the previous database. In EBSCO search there were two works that were already reported in the previous databases. In the Web of Science, nine works were obtained, where only two were new finds. In Springer link no article was found related to J. dioica in the title, giving a total of 11 works that involved the appearance of J. dioica in the title.

Figure 2 also shows the trend of publication about J. dioica from 1970 to 2018. Among them are just few studies related to composition, pharmacology, and toxicology of J. dioica. From 1970 to 2010, 2 publications were found; however, from to 2011 to 2018, the number of investigations increased up to 09. The increase in the number of publications is most likely due to the need for finding new sources of highly effective, economic, and harmless medications. This sudden jump in the number of publications demonstrates that J. dioica is a plant of rising interest, though not much studied by Mexican and world researchers (UNAM, 2010; Wong-Paz et al., 2010).

Botanical aspects

The botanical description of J. dioica (Figure 3) is: Kingdom: Plantae; Clade: Magnoliophyta; class: Magnoliopsida; Order: Malpighiales; Family: Euphorbiaceae; Subfamily: Crotonoideae; Tribe: Jatrophereae; Genus: Jatropha; Species: dioica (UNAM, 2010). This species inhabits areas with a dry and semi-dry clime, such as the territory of Texas, USA and the Northern Mexico, even though it can be found throughout the Mexican territory (Flores-Torres et al., 2019; Gutiérrez et al., 2018). J. dioica is a shrub of 50 to 150 cm in height, reddish-brown branches with narrow, long, and dark green leaves. The flowers are grouped in cymes, the male flowers are small while females are bigger, with a light pink color (UNAM, 2010).
Search Database: Pubmed/Medline, Web of science, ScienceDirect, EBSCO, SCOPUS and Springerlink (n = 681)

Removal of articles that lacked descriptor in the title (n = 654)

Removal of repeated articles (n = 16)

Included articles for the descriptors appearance in the title and publication in the years range selected for systematic analysis (n = 11)

Figure 1. Flow diagram of the selection criteria for articles of interest.

Figure 2. The number of publications over the last 40 years related to J. dioica plant family and publications of research related to the plant J. dioica found in different databases. A: Search of articles that contain descriptor in the title. B: Articles that contain descriptor in the title selected for this systematic analysis by decade.
The plants bloom in spring and early summer. The fruits are globose with seeds inside (Eggli, 2001; Valenzuela Soto, 2014).

**Traditional usage of J. dioica**

From a medical stand point, the use of *J. dioica* is diverse and has been attributed to each of the parts that make up this plant. Endemic to Mexico, this plant is known by different names throughout the country: batacora (Baja California), coatli and dexthi (Hidalgo), drago, felondilla and gualulo (Hidalgo), matacora (Baja California), piñon de cerro, sangre de drago (Hidalgo, Valle de Mexico), sangre de grado (Durango, Valle de Mexico), sangre gaco, sangregada and sangregado (Coahuila, Durango, Sinaloa, Sonora), sangregrado (Durango, San Luis Potosi, Sonora, Zacatecas), sangregrao and suzi (Oaxaca), tacote prieto (Sinaloa, Sonora), telondilla (Ciudad de Mexico, Hidalgo), tlapalezapati (Nahuatl), torote amarillo and torote prieto (Baja California) (Manzanero-Medina et al., 2009).

The root is macerated or boiled in order to extract a liquid which is then used to rinse the hair and slow hair loss (Razo Rodriguez and Alvarado Bárcenas, 2014). Similarly, once boiled, the resulting liquid can be used as bath water to cleanse wound infections (Wong-Paz et al., 2010), weakness, kidney pains and problems with absorption (Manzanero-Medina et al., 2009). In order to treat these illnesses, a fistful of roots should be boiled in approximately three or four liters of water (Castillo et al., 2010). Due to its high tannin content, it is used as a dye, a preservative and mainly to tan animal skins (Castillo et al., 2010). It also functions as an antibiotic. It treats periodontist, and also alleviates pain when the roots or stalk are chewed. It reduces inflammation of the venous and respiratory passages (ulcers and hemorrhoids), cures acne and other skin allergies and treats dandruff and itching (Bravo Luna et al., 2000) in addition to healing wounds (Ocegueda, 2005).

The stalk is utilized in the treatment of colon, prostate, cervical, tongue, stomach and skin cancers in their early stages (Martínez et al., 2014). Drops of liquid extracted from the stalk are then mixed in a liter of water and taken daily (Barba Avila et al., 2003). It is also used against ascorbic acid deficiency (Oropeza Dominguez, 2006).

The leaf and seeds are consumed as laxatives (Can-Aké et al., 2004). It is also said to be useful in the treatment of sore eyes, the elimination of cloudiness of vision and blindness. To do so, the fruit is squeezed, thereby allowing a few drops to fall directly into the eye (Arturo et al., 1994). It has also been reportedly used against scleral diseases (Valenzuela Soto, 2014). Oil extracted from the seeds is used to treat oral blisters, eczema and itchiness. This oil contains phenolic components, which promote biological antifungal activity (Pabón and Hernández-Rodríguez, 2012).

**Antimicrobial and antifungal activity**

The extracts of *J. dioica* has shown different antimicrobial activity depending on the solvent used in the preparation and the part of the plant used. Root extract made with hexanol was more potent than extracts made with alcohol and acetone. These extracts were evaluated in human pathogens such as *Bacillus cereus*, *Escherichia coli*, *Salmonella Typhi*, *Staphylococcus aureus*, *Enterobacter aerogenes*, *Enterobacter cloacae*, *Salmonella typhimurium*, *Cryptococcus neoformans*, *Candida albicans*, *Candida parapsilosis*, and *Sorothrix schenckii*. This high antibacterial and antifungal activity may come from the presence of β-sitosterol (terpene) compounds in the plant (Silva-Belmares et al., 2014).
Soxhlet extracts of roots prepared with different solvent concentration were evaluated against S. aureus, E. coli, Serratia marcescens, Pseudomonas aeruginosa, Streptococcus mutans (strands 35531 and 31377), and Klebsiella pneumoniae (strands 042, 88142, 17-2, 88145, and 49766) (Escareño-Piña, 2017; Terrazas-Hernández et al., 2018). Hexane extract showed the best inhibitory behavior with the lowest minimum inhibitory concentration against S. mutans and Klebsiella pneumoniae. In other studies, methanol extracts were assessed for the activity against S. aureus and K. pneumonia (Dominguez et al., 1980; Serrano-Gallardo et al., 2017). Studies indicate that the hydro-alcoholic extracts of the root has an activity against C. albicans (Alanis-Garza et al., 2007), which was confirmed by others (Oliveira Simone et al., 2013) who also determined the minimum inhibitory concentration and minimum fungicidal concentration leaves and roots extracts. This plant has been used as a tooth strengthening remedy, thus the ethanolic root extracts (Terrazas-Hernández et al., 2018) and aqueous plant extracts (Vargas-Segura et al., 2018) were recently evaluated against S. mutans and the minimum inhibitory concentration and half maximal inhibitory concentration were determined to be 2 mg/mL and 250 ppm, respectively.

Antiviral effect

Silva-Mares et al. (2013) reported that J. dioica root hydro-methanolic extract showed antiviral activity against herpes type 1 and type 2 (HSV-1 and HSV-2, respectively). The fractions of hexane were analyzed chromatographically, indicating the presence of metabolite diterpene (riolozatrione) as the main compound. The authors also mentioned that the extract displayed slight cytotoxicity.

Hypoglycemic effect

Within the family Euphorbiaceae, the genus Jatropha has been considered as a therapeutic alternative for the treatment of diabetes mellitus (DM) (Aladodo et al., 2013; Kumar et al., 2016). Other studies show the hypoglycemic effect of the phenolic fraction and ethanolic extract isolated from leaves of Jatropha aethiopica. The authors deduced that the ethanolic extract as the phenolic fraction contributes to the improvement of glucose tolerance, but the ethanolic extract exhibited a relatively greater effect compared to a biguanide such as metformin (Gamieteab-Turro et al., 2018).

The study by Rahju et al. (2013) evaluated Jatropha gossypifolia L. extracts against type 2 diabetes mellitus. They found a significant lowering of blood glucose level in DM-induced rats. The authors suggested that the extracts probably have insulin secretaceous activity related to inhibitory activity for α-glucosidase, enzyme hydrolase, essential for the catabolism of glycogen to glucose in the lysosomes, thus reducing the absorption of carbohydrates from the digestive tract, which can stop the release of D-glucose, thus reducing the plasma glucose levels (Sevilla-Asencio et al., 2013). Another study by Granados et al. (2015) showed an improvement in glucose absorption and tolerance on two cell models (Myotubes C2C12 and adipocytes 3T3-L1), with exposure to extracts of J. gossypifolia for 4 h, in vivo.

Hypoglycemic activity has been attributed to extracts of Jatropha curcas leaves showing improvement of changes in lipid metabolism in DM alloxan induced rats, significantly reducing glucose levels, more so at a higher dose (Patil et al., 2011), which could be attributed to the presence of specifically expressed sequence tags in that plant (Sahu et al., 2014). J. dioica also has shown to have hypoglycemic activity (Alarcon et al., 1998).

Antioxidant activity and genoprotector effect of J. dioica

The presence of terpenoids compounds, flavonoids, reducing sugars and alkaloids are possibly responsible for the antioxidant effect observed using model radical scavenger (1, 1-diphenyl-2-picrylhydrazyl, DPPH) for the root extracts of J. dioica (Wong-Paz et al., 2014). Similarly, the plant extracts show a genoprotector effect on mouse liver, renal and bone marrow cells evaluated with comet assay (Martínez et al., 2014; Ramírez-Moreno et al.). Using root extract of J. dioica showed that antioxidant activity is directly proportional to the amount of polyphenols in hydro-alcoholic (Ramírez et al., 2016).

The antioxidant capacity was demonstrated using a radical scavenger’s DPPH and radical cation scavenger (2,2-azino-bis 3 ethyl benzothiazoline-6- sulfonic acid) ABTS relating it to the presence of phenolic compounds in the plant (Wong-Paz et al., 2015). Studies looked at the sterilization effect on the extracts of J. dioica root (Terrazas-Hernández et al., 2018). They reported that even though the high temperatures of sterilization increased total phenolic content (TPC) and changed the color of the solution (Maillard reactions), it did not influence its antioxidant activity (DPPH and ABTS arrays) or antibacterial behavior against S. mutans. TPC also depends on the climate condition and extraction method (Gutiérrez-Tláaque et al., 2018), with winter drought, UV exposure, and solvent composition higher in alcohol increasing the concentration and antioxidant activity. Similarly, solvent composition (% alcohol) and extraction method (heat reflux vs. ultrasound-assisted) can strongly influence the amount of TPC in the plant extract (Wong-Paz et al., 2014).
Chemical composition

Some ethnobotanical uses may be attributed to the presence of secondary metabolites such as polyphenols (Aguilera-Carbo et al., 2008). The studies carried out in *J. dioica* have identified characteristic chemicals such as steroid alcohols (Burgueño-Tapia et al., 2017), flavonoids, tannins (Mendoza-Moreno, 2000), and terpenes, among others (Perroni et al., 2014). Figure 4 shows the chemical structure of the compounds reported in *J. dioica*. Overall, this plant is a good candidate to obtain nutraceutical and functional ingredients due to the amount of polyphenols present (Wong-Paz et al., 2014).

Cytotoxicity

The extracts of *J. dioica* do not show toxicity or low cytotoxicity at concentrations used in literature. Studies carried out in micronuclei of peripheral blood of mouse
Similarly, reports many Mexican Indians, who used the latex of J. dioica to relieve liquid or frequent bowel movements, and to remove thorns from the skin (Latorre et al., 1977). An interesting report (González and González-Chávez, 2006) indicates that J. dioica has the ability to accumulate zinc, cadmium, and nickel from mining-polluted soils. Recently, aqueous J. dioica extract was used as a reducing agent in synthesis if zinc oxide nanoparticles (Villanueva-Ibáñez et al., 2018), however, the authors did not dwell on the function of the extract’s composition. Table 1 shows the pharmacological activity of J. dioica.

### Table 1. Pharmacological activity of J. dioica.

| Group       | Compound       | Activity                                                                 | Reference                                         |
|-------------|----------------|--------------------------------------------------------------------------|--------------------------------------------------|
| Sterols     | Jatropha B     | Antitumor effect, gastroprotective activity.                             | Melchor-Martínez et al. (2017), Pertino et al. (2006) |
|             | R-sitosterol   | Chemo-protective activity against colon cancer, using in vitro and in vivo models. | Baskar et al. (2010).                             |
|             | Citalatrine    | Antiviral and antitumor effect.                                          | Dominguez et al. (1980), Melchor-Martínez et al. (2017) |
|             | Riolosatrine   | Its bioactivity has not been evaluated                                    |                                                  |
|             | Triterpenes    | Antibiotic activity against Staphylococcus aureus.                       | Chen et al. (1994).                              |
| Flavonoids  | Quercetin      | Protects against glucotoxicity preventing the aggregation and functional loss of proteins.  | Civelek et al. (2019), Sati et al. (2019)         |
|             |                | Antimicrobial activity against fungi and bacteria: Gram-positive and Gram-negative. |                                                  |
|             | Catechin       | Regulates the bioavailability of nitric oxide, improving endothelial function among people with high blood pressure, diabetes, and heart disease | Galleano et al. (2010)                           |
| Polyphenols | Tannins        | Antitumor and antibacterial activity, a strong inhibitor of E. coli.     | Chen et al. (1994).                              |
| Phenols     | Ellagic acid   | Antioxidant, antimicrobial, and antiparasitic properties. Antitumor effect by inhibiting the mutation of healthy cells in bladder preventing cancer. | Ascacio-Valdés et al. (2013)                      |
|             | Gallic acid    | Antioxidant activity and antibacterial effect against E-coli.            | Baquero and Gordillo (2013).                      |

(Table continued)

(Received BALB-C) using the aqueous extract of root of J. dioica showed no cytotoxic effect nor genotoxic (Araujo-Espino et al., 2017). Similarly, aqueous and ethanol extracts from leaves and roots showed low cytotoxicity in 3T3/NF mouse fibroblasts measured photometrically in a 3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide assay after a 24 h exposure (Oliveira Simone et al., 2013).

Other properties of J. dioica

According to the digital library of traditional Mexican medicine (UNAM, 2010), this plant has many traditional medicinal uses. There are reports of an ancestral use by the Kickapoo Indians, who used the latex of J. dioica to relieve... few scientific reports on the medical and nutritional properties attributed to this plant. The antioxidant capacity of this plant has been mostly investigated, however, there is still insufficient analysis of these. The extracts of J. dioica were found to be used as a protector or antioxidant, yet there is no literature report of human studies. There is not enough systematic evidence to ensure that the ethnobotanical use of this plant is... (strain BALB-C) using the aqueous extract of root of J. dioica showed no cytotoxic effect nor genotoxic (Araujo-Espino et al., 2017). Similarly, aqueous and ethanol extracts from leaves and roots showed low cytotoxicity in 3T3/NF mouse fibroblasts measured photometrically in a 3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide assay after a 24 h exposure (Oliveira Simone et al., 2013).
CONFLICT OF INTERESTS
The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS
The authors appreciate CONACYT for granting a graduate scholarship to Ramírez-Moreno A.  

REFERENCES
Aggie H (2010). Leatherstem, Sangra de Drago, Sangre de Grado, Tocote Prieto, Tocote Prieto, Telodilido, Tlapazapatlí, Pinon del Cerro, Coatlí, Torte Amarillo, Drago Jatropha dioica Euphorbiaceae. Retrieved February 17, 2018, from https://aggio-horticulture.tamu.edu/ornamentals/nativeshrubs/jatrophaedic.htm
Aguilera-Barco AF, Augur C, Prado-Barragan LA, Aguilar CN, Favela-Torres E (2008). Extraction and analysis of ellagic acid from novel complex sources. Chemical Papers 62(4):440-444. https://doi.org/10.2478/s11696-008-0424-3
Alabedo RA, Muhammad NO, Balogun EA (2013). Effects of Aqueous Root Extract of Jatropha curcas on Hyperglycemic and Haematological Indices in Allxan-induced. Fountain Journal of Natural and Applied Sciences 2(1):52-58.
Alarcon-Aguilara FJ, Roman-Ramos R, Perez-Gutierrez S, Aguilar-Contreras A, Contreras-Weber CC, Flores-Saenz JL (1998). Study of the anti-hyperglycemic effect of plants used as antidiabetics. Journal of Ethnopharmacology 61(2):101-110. https://doi.org/10.1016/S0378-8741(98)00020-8
Alanís-Garza BA, González-González GM, Salazar-Aranda R, Waksman de Torres N, Rivas-Galindo VM (2007). Screening of antifungal activity of plants from the northeast of Mexico. Journal of Ethnopharmacology 114(3):468-471. https://doi.org/10.1016/j.jep.2007.08.026
Araujo-Dominguez TC, Zamora-Pérez AL, Zúñiga-González GM, Gutiérrez-Hernández R, Morales-Veláquez G, Lazalde-Ramos BP (2017). Genotoxic and cytotoxic evaluation of Jatropha dioica Sessé ex Cerv. by the micronucleus test in mouse peripheral blood. Regulatory Toxicology and Pharmacology 86:260-264. https://doi.org/10.1016/j.yrtph.2017.03.017
Arturo AV, Asseleh LMC, María Elena, R (1994). Atlas de las plantas medicinales de la medicina tradicional mexicana. (B. de la medicina tradicional mexicana, Ed.) (1st ed.). México, D.F.
Ascasio-Valdés JA, Aguilera-Carbó A, Rodríguez-Herrera R, Aguilar-González C, Alberto J, Valdés A (2013). Determination of ellagic acid in native plants from the Mexican semi-desert. Revista Mexicana de Ciencias Farmacéuticas 44(2).
Barba Avila MD, Croce Hernandez M, Cerda Lemus M (2003). Plantas Utiles de la región semiárida de Aguascalientes (U. A. de Aguascalientes, Ed.) (1a ed.) (ed.). México.
Baquer LCP, Gordillo JV (2013). Actividad antioxidante y antibacteriana de extractos de hojas de cuatro especies agroforestales de la Orinoquia colombiana. Revista Cubana de Plantas Medicinales 18(1):57-60. Retrieved from http://scielo.sld.cu/pdf/pla/v18n1/pla08113.pdf
Baskar A, Ignacimuthu S, Paujul GT, Al Numair KS (2010). Chemopreventive potential of β-Sitosterol in experimental colon cancer model - An In vitro and In vivo study. BMC Complementary and Alternative Medicine 10(24):1-10. https://doi.org/10.1186/1472-6882-10-24.
Bravo Luna L, Bermúdez Torres K, Montes Belmont R (2000). Inhibición de Fusarium moniliforme mediante polvos vegetales y algunos de sus componentes químicos. Retrieved February 1, 2018, from https://biblat.unam.mx/es/revista/manejo-integrado-de-plagas/articulo/inhibicion-de-fusarium-moniliforme-mediante-polvos-vegetales-y-algunos-de-sus-componentes-quimicos
Burgueño-Tapia E, Chávez-Castellanos K, Cedillo-Portugal E, Joseph-Nathan P (2017). Absolute configuration of diterpenoids from Jatropha dioica by vibrational circular dichroism. Tetrahedron Asymmetry 28(1):166-174. https://doi.org/10.1016/j.tetasy.2016.11.006.
Can-Áké R, Erosa-Rejón G, May-Pat F, Peña-Rodríguez LM, Peraza-Sánchez SR (2004). Bioactive terpenoids from roots and leaves of Jatropha gaumeri. Revista de La Sociedad Química de México 48(1):11-14.
Castillo F, Hernández D, Gallegos G, Mendez M, Rodríguez R, Reyes A, Aguilar CN (2010). In vitro antifungal activity of plant extracts obtained with alternative organic solvents against Rhizoctonia solani Kühn. Industrial Crops and Products 32(3):324-328. https://doi.org/10.1016/j.indcrop.2010.05.013
Chandran R, Pramelazhagan T, Shanmugam S, Thankarajan S (2016). Antidiabetic activity of Syzygium calophyllum in Streptozotocin-Nicotinic acid Induced Type-2 diabetic rats. Biomedicine and Pharmacotherapy 82:547-554. https://doi.org/10.1016/j.biopharm.2016.05.036
Chen Z, Cai Y, Phillipson D (1994). Studies on the Anti-Tumour, Antioxidant, and Wound- Healing Properties of Dragon’s Blood. Planta Medica 60:541-545.
Cirilo Aguilar B, Cantú Martínez P, Cerro M, Mata Cárdenas B (2011). Use of the Herbolaria in the Care of the Patient. Revista de Salud Pública y Nutrición 12(2):1-6.
Civelek M, Flory S, Meloh H, Fitzenberger E, Wenzel U (2019). The polyphenol quercetin protects from glucotoxicity depending on the aggressor in Caenorhabditis elegans. European Journal of Nutrition 1-7. https://doi.org/10.1007/s00394-019-01917-6
Dominguez GC, Franco R, Villareal A (1980). Riozilatozina, a new class diterpene from Jatropha dioica var: sessiliflora (roots). Retrieved February 17, 2018, from http://agris.fao.org/agris-search/search.do?recordID=GB1981064472
Egli U (Ed.). (2001). Illustrated Handbook of Succulent Plants: Monocotyledons (1st ed.). Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-642-56715-5
Espadarte-Piria E (2017). Acción antimicrobiana de extractos de Jatropha dioica en Cerv. Unidad Acad Ondont 57-63.
Flores-Torres A, Montaña C, Franco M (2019). Coexistence and the niche in a nurse–cactus interaction: Is cyclic dynamics justified? Journal of Ecology 107(1):407-417. https://doi.org/10.1111/1365-2745.13015
Fresnedo-Ramírez J, Orozco-Ramírez Q (2013). Diversity and distribution of genus Jatropha in Mexico. Genetic Resources and Crop Evolution 60(3):1077-1104. https://doi.org/10.1007/s10722-012-9865-7.
Galleano M, Pechanoa OG, Fraga C (2010). Hypertension, Nitric Oxide, Oxidants, and Dietary Plant Polyphenols. Current Pharmaceutical Biotechnology 11(8):837-848. https://doi.org/10.2174/138920110793262114
Gamio-Turro D, Camaforte NAP, Valerino A, Ortiz Nuñez Y, Rinaldo D, Dokkedal AL (2018). Qualitative and Quantitative Analysis of Ethanolic Extract and Phenolic Fraction of Jatropha aethiopica (Euphorbiaceae) Leaves and Their Hypoglycemic Potential. Journal of Agricultural and Food Chemistry 66(6):1419-1427. https://doi.org/10.1021/acs.jafc.7b05648
González RC, González-Chávez MCA (2006). Metal accumulation in wild plants surrounding mining wastes. Environmental Pollution 144(1):84-92. https://doi.org/10.1016/j.envpol.2006.01.006
Govea-Salas M, Morlett-Chávez J, Rodríguez-Herrera R, Ascáriz-Valdés J (2017). Some Mexican Plants Used in Traditional Medicine. In INTECH (Ed.). Aromatic and Medicinal Plants - Back to Nature (1ra ed., pp. 191-200). https://doi.org/10.5772/66637
Granados S, Balcazar N, Guillon A, Echeverri F (2015). Evaluation of the hypoglycemic effects of flavonoids and extracts from Jatropha gossypifolia Molecules 20(4):6181-6183. https://doi.org/10.3390/molecules20046181
Gutiérrez-Tlahque J, Aguirre-Mancilla CL, Raya-Pérez JC, Ramírez-Pimentel JM, Jiménez-Alvarado R, Hernández-Fuentes AD (2018). Effect of climate conditions on total phenolic content and...
antioxidant activity of Jatropha dioica Cerv. var. dioica. Ciencia e Investigación Agraria 45(1):70-81. https://doi.org/10.7764/ci.451.1832

Gutiérrez M, Pando-Moreno M, Jurado E, González-Rodríguez H, Marmolejo JG, Mendoza D (2018). Non-random distribution of biocrust in a natural arid environment in the northern Mexican plateau. Applied Ecology and Environmental Research 16(3):2441-2451. https://doi.org/10.15666/aeer/1603_24412451

Kim J, Jho KH, Choi YH, Nam, SY (2013). Chemopreventive effect of cactus (Opuntia humifusa) extracts: Radical scavenging activity, pro-apoptosis, and anti-inflammatory effect in human colon (SW480) and breast cancer (MCF7) cells. Food and Function 4(5):681-688. https://doi.org/10.1039/c3fo30287c

Kumar J, Singh SP, Choudhary GK (2016). Pharmacological evaluation of leaves of Jatropha curcas L. for anti-diabetic activity in alloxan induced diabetic rats. Indian Journal of Animal Sciences 86(4):387-392.

Latorre D, Latorre F (1977). Plants used by the Mexican Kickapoo Indians. Economic Botany 31:340-357.

Manzano-Medina GI, Alejandro FM, Sandoval-Zapotitlán E, Bye-Boettler R (2009). Etnobotánica de Siete Raíces Medicinales en el mercado de Sonora de la Ciudad de México. Polibotánica 27:191-228. Retrieved from https://www.redalyc.org/articulo.oa?id=2111396011

Martínez N, Almaguer G, Vázquez-Alvarado P, Figueroa A, Zúñiga C, Hernández-Cereules A (2014). Análisis fitoquímico de Jatropha dioica y determinación de su efecto antidiabético y quimioprotector sobre el potencial genotóxico de ciclofosfamida, daunorubicina y metilmetanosulfonato evaluado mediante el ensayo comet. Boletín Latinoamericano y Del Caribe de Plantas Medicinales y Aromáticas 19(1):437-457.

Melchor-Martínez EM, Silva-Mares DA, Torres-López E, Waksman-Minsky N, Pauli GF, Chen SN (2017). Stereochrome of a Second Riolozane and Other Diterpenoids from Jatropha dioica. Journal of Natural Products 80(8):2252-2262. https://doi.org/10.1021/acs.jnatprod.7b00193

Mendoza-Moreno JC (2000). Cuantificación de Taninos condensados de corteza y madera en la especie Sangre de Drago (Jatropha dioica). Retrieved February 1, 2018, from https://docplayer.es/37312607-Cuantificacion-de-taninos-condensados-de-corteza-y-madera-en-la-especie-sangre-de-drago-jatropha-dioica.html

Oceguera S (2005). Plantas utilizadas en la medicina tradicional mexicana y su identificación científica. BioDiversitas. México.

Olivera Simone GD, Estilla AM, Cordero AM, Hidalgo et al. (2014). Importancia química de Jatropha curcas y sus aplicaciones biológicas, farmacológicas e industriales. Revista Cubana de Plantas Medicinales 17(2):194-209. Retrieved from http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0110-1721201400020001

Patil RN, Patil RY, Aihwar B, Ahikwar D (2011). Evaluation of antidiabetic and related actions of some Indian medicinal plants in diabetic rats. Asian Pacific Journal of Tropical Medicine 4(1):20-23. https://doi.org/10.1016/S1995-7645(11)60025-4

Perroni Y, García-Oliva F, Souza V (2014). Plant species identity and soil P forms in an oligotrophic grassland-desert scrub system. Journal of Arid Environments 108:29-37. https://doi.org/10.1016/j.jaridenv.2014.04.009

Pertino M, Rodríguez JA, Theodulioz C, Ramlisch I, Schmeda-Hirschmann G (2006). Gastroprotective activity and cytotoxic effect of Jatropha dioica acid derivatives. Journal of Pharmacy and Pharmacology 58(11):1507-1513. https://doi.org/10.1211/jpp.58.11.0012

Rahuj A, Mishra A, Maurya R, Srivastava MN, Tamrakar AK, Jain SK, Srivastava AK (2013). Antidiabetic and hypolipidemic activity in stem of Jatropha gossypifolia L. International Journal of Pharmacy and Pharmaceutical Sciences 4(7):706-715.

Ramirez Moreno A, Serrano Gallardo LB, Barragán Ledezma L, Barragán Ledezma E, Pérez-Verti A, Daniel R, Delgadillo Guzmán D (2016). Determinación de los compuestos polifenólicos en extractos de Jatropha dioica y su capacidad antioxidante. Revista Mexicana de Ciencias Farmacéuticas 47(4):42-47. Retrieved from http://www.redalyc.org/articulo.oa?id=57596612004

Ramírez García C, Alvarado Bárceñas E (2014). Captosan tónico capilar de sangregado (Jatropha dioica). Jóvenes En La Ciencia 1(1):493-497.

Sahu J, Sen P, Choudhury MD, Dehury B, Barooah M, Modi MK, Talukdar A (2014). Rediscovering Medicinal Plants’ Potential with OMICS: Microsatellite Survey in Expressed Sequence Tags of Eleven Traditional Plants with Potent Antidiabetic Properties. OMICS: A Journal of Integrative Biology 18(5):298-309. https://doi.org/10.1089/omi.2013.0147

Sati P, Dhyani P, Bhatt ID, Pandey A (2019). Ginkgo biloba flavonoids glycosides in antimicrobial perspective with reference to extraction method. Journal of Traditional and Complementary Medicine 9(1):15-23. https://doi.org/10.1016/j.jtcm.2017.10.003

Serrano-Gallardo LB, Castillo-Maldonado I, Borjín-Ríos CG, Rivero-Guillén MA, Montaño-Jémez J, Téllez-López MA (2017). Antimicrobial activity and toxicity of plants from northern Mexico. Indian Journal of Traditional Knowledge 16(2):203-207.

Sevilla-Aseco OA, Dublán-García O, Gómez-Olíván LM, López-Martínez LX (2013). Actividad inhibidora sobre α-glucosidasa y α-amilasa de extractos acuosos de algunas especias utilizados en la cocina mexicana. CienciaUAT 8(1):42-47. https://doi.org/10.29059/cienciauat.v8i1.6

Sharma SK, Singh H (2012). A review on pharmacological significance of genus Jatropha (Euphorbiaceae). Chinese Journal of Integrative Medicine 18(11):868-870. https://doi.org/10.1007/s11655-012-1267-8

Silva-Belmares Y, Rivas-Morales C, Viveros-Valdez E, Cruz-Galicia MG, Carranza-Rosasales P (2014). Antimicrobial and Cytotoxic Activities from Jatropha dioica Roots. Pakistan Journal of Biological Sciences 17(5):748-750. https://doi.org/10.3923/pjbs.2014.748.750

Silva-Mares D, Torres-López E, Rivás-Estilla AM, Cordero-Pérez P, Waksman-Minsky N, Rivás-Galindo VM (2013). Plants from northeast Mexico with anti-HSV activity. Natural Product Communications 8(3):297-298. https://doi.org/10.17177/1934578X1300800305

Tarrazas-Hernández J, Santos-López E, Carriño-Cortés R, Jiménez-Alvarado R, López-Palestina C, Hernández-Fuentes A (2018). Effects of Sterilization on Bioactives of Jatropha dioica and Opuntia oleracea. A Tentative Step Toward Biocompatible Capacity against Streptococcus mutans. Applied Sciences 8(12):1-15. https://doi.org/10.3390/app8122516

UNAM (2010). Biblioteca digital de la medicina tradicional mexicana. Retrieved February 1, 2018, from http://www.medicadintradicionalmexicana.unam.mx/monografia.php?f=3&f=Sangre_de_dra_go_o_sangregado&St=4783

Valenzuela Soto R (2014). Compuestos activos con capacidad hipoglucemiante en Cnidoscolus chayamansa (Chaya), Euphorbia prostrata (Hierba de la Golorinda) y Jatropha dioica (Sangre de Drago). Universidad Autónoma de Nuevo León.

Vargas-Segura AI, Silva-Belmares SY, Segura-Cenícero EP, Ascacio-Valdés JA, Méndez-González L, Iliana A (2018). Screening and characterization of medicinal plants extracts with bactericidal activity against Streptococcus mutans. Natural Product Research, pp. 1-5. https://doi.org/10.1080/14786741.2018.1550757

Villanueva-Ibáñez M, González Montes de Oca R, Camargo Pérez VP, Olivera-Venegas PN, Martínez Pérez AI, Vera Cárdenas EE, Flores-González MA (2018). Microstructural Characterization of Biosynthesized ZnO Nanostructures Using Jatropha dioica Aqueous Extract. Microscopy and Microanalysis 24(Suppl. 1):1422-1423. https://doi.org/10.1007/s11010-018-2170-x

Wong-Paz JE, Castillo-Inungara ML, López-López LI, Contreras-Esquível JC, Nevárez-Moorillon GV, Aguilar CN (2010). Jatropha dioica: Fuente potencial de antimicrobianos. Revista Científica de La...
Universidad Autónoma de Coahuila 2(4):1-5. Retrieved from file:///J:/arboles/Usos arboles de Mexico/Referencias/Nacional/Jatropha dioica agentes antimicrobianos.pdf

Wong-Paz JE, Contreras-Esquivel JC, Muñiz-Marquez D, Belmares R, Rodríguez R, Flores P, Aguilar CN (2014). Microwave-assisted extraction of phenolic antioxidants from semi-arid plants. American Journal of Agricultural and Biological Science 9(3):299-310. https://doi.org/10.3844/ajabssp.2014.299.310.

Wong-Paz JE, Muñiz-Márquez DB, Aguilar-Zárate P, Rodríguez-Herrera R, Aguilar CN (2014). Microplate quantification of total phenolic content from plant extracts obtained by conventional and ultrasound methods. Phytochemical Analysis 25(5):439-444. https://doi.org/10.1002/pca.2512

Wong-Paz JE, Contreras-Esquivel JC, Rodríguez-Herrera R, Carrillo-Inungaray ML, López KL, Nevárez-Moorillón GV, Aguilar CN (2015). Total phenolic content, in vitro antioxidant activity and chemical composition of plant extracts from semi-arid Mexican region. Asian Pacific Journal of Tropical Medicine 8(2):104-111. https://doi.org/10.1016/S1995-7645(14)60299-6

Wong Paz JE, Muñiz Márquez DB, Martínez Ávila GCG, Belmares Cerda RE, Aguilar CN (2015). Ultrasound-assisted extraction of polyphenols from native plants in the Mexican desert. Ultrasonics Sonochemistry 22:474-81. https://doi.org/10.1016/j.ultsonch.2014.06.001.