

## Biological activities associated with tannins and flavonoids present in *Hymenaea stigonocarpa* and *Hymenaea courbaril*: A systematic review

Atividades biológicas associadas a taninos e flavonoides presentes em *Hymenaea stigonocarpa* e *Hymenaea courbaril*: Uma revisão sistemática

Actividades biológicas asociadas con taninos y flavonoides en *Hymenaea stigonocarpa* y *Hymenaea courbaril*: Una revisión sistemática

Received: 08/17/2022 | Reviewed: 08/29/2022 | Accept: 09/02/2022 | Published: 09/10/2022

**Cléber José da Silva**

ORCID: <https://orcid.org/0000-0001-9871-4228>  
Federal University of Pernambuco, Brazil  
E-mail: [cleber.josesilva@ufpe.br](mailto:cleber.josesilva@ufpe.br)

**Erika de Arruda Nascimento**

ORCID: <https://orcid.org/0000-0003-0754-6770>  
Federal University of Pernambuco, Brazil  
E-mail: [erikanasto@gmail.com](mailto:erikanasto@gmail.com)

**Bruno Iraquitã Miranda da Silva**

ORCID: <https://orcid.org/0000-0002-0633-5261>  
Federal University of Pernambuco, Brazil  
E-mail: [bruno.iraquitã@ufpe.br](mailto:bruno.iraquitã@ufpe.br)

**Márcia Silva do Nascimento**

ORCID: <https://orcid.org/0000-0002-4512-4715>  
Federal University of Pernambuco, Brazil  
E-mail: [marcia.nascimento@ufpe.br](mailto:marcia.nascimento@ufpe.br)

**Jaciana dos Santos Aguiar**

ORCID: <https://orcid.org/0000-0002-6097-8065>  
Federal University of Pernambuco, Brazil  
E-mail: [jaciana.aguiar@ufpe.br](mailto:jaciana.aguiar@ufpe.br)

### Abstract

The genus *Hymenaea* belongs to the Fabaceae family and has species distributed from Central America to South America in the Amazon. The wood of these species are widely used in civil construction, as well as the leaves, roots, sap and bark to treat inflammatory and respiratory diseases, infections, tumors and pain. This systematic review aimed to identify the biological activities associated with tannins and flavonoids in *Hymenaea courbaril* and *Hymenaea stigonocarpa*. Thus, research articles published between 2009 and 2019 that directly address this topic were searched using the following descriptors: *Hymenaea* AND flavonoids AND tannins AND biological activities AND medicinal plant, in PubMed Central, Web of Science, Scopus and Science Direct databases. The results obtained suggest that tannins and flavonoids are among the main compounds involved with potential antifungal and termiticidal effects, in addition to antioxidant, antibacterial, antidiarrheal, antiulcer, anti-inflammatory, myorelaxant, antiviral and larvicidal action for *Aedes aegypti*. The phytochemical diversity of these plants and the various biological activities help to expand scientific knowledge about these species, contributing to the eventual production of new products and/or new technologies.

**Keywords:** Fabaceae; Medicinal plants; *Hymenaea courbaril*; *Hymenaea stigonocarpa*; Phenolic compounds; Biological activity.

### Resumo

O gênero *Hymenaea* pertence à família Fabaceae e possui espécies distribuídas da América Central à América do Sul na Amazônia. As madeiras dessas espécies são amplamente utilizadas na construção civil, assim como as folhas, raízes, seiva e casca para tratar doenças inflamatórias e respiratórias, infecções, tumores e dores. Esta revisão sistemática teve como objetivo identificar as atividades biológicas associadas aos taninos e flavonóides em *Hymenaea courbaril* e *Hymenaea stigonocarpa*. Assim, os artigos de pesquisa publicados entre 2009 e 2019 que abordam diretamente esse tema foram pesquisados usando os seguintes descritores: *Hymenaea* AND flavonoids AND tannins AND atividades biológicas AND planta medicinal, nas bases de dados PubMed Central, Web of Science, Scopus e Science Direct. Os resultados obtidos sugerem que os taninos e flavonoides estão entre os principais compostos envolvidos com potenciais efeitos antifúngicos e termiticidas, além de ação antioxidante, antibacteriana, antidiarreica, antiúlcera, anti-inflamatória, miorelaxante, antiviral e larvicida para o *Aedes aegypti*. A diversidade fitoquímica

dessas plantas e as diversas atividades biológicas ajudam a ampliar o conhecimento científico sobre essas espécies, contribuindo para a eventual produção de novos produtos e/ou novas tecnologias.

**Palavras-chave:** Fabaceae; Plantas medicinais; *Hymenaea courbaril*; *Hymenaea stigonocarpa*; Compostos fenólicos; Atividade biológica.

### Resumen

El género *Hymenaea* pertenece a la familia Fabaceae y tiene especies distribuidas desde América Central hasta América del Sur en la Amazonía. Las maderas de estas especies son muy utilizadas en la construcción civil, al igual que las hojas, raíces, savia y corteza para tratar enfermedades inflamatorias, respiratorias, infecciones, tumores y dolores. Esta revisión sistemática tuvo como objetivo identificar las actividades biológicas asociadas con taninos y flavonoides en *Hymenaea courbaril* e *Hymenaea stigonocarpa*. Así, se buscaron artículos de investigación publicados entre 2009 y 2019 que abordan directamente este tema utilizando los siguientes descriptores: *Hymenaea* AND flavonoids AND tannins AND Biological Activities AND Medicinal Plant, en las bases de datos PubMed Central, Web of Science, Scopus y Science Direct. Los resultados obtenidos sugieren que los taninos y los flavonoides se encuentran entre los principales compuestos involucrados con potenciales efectos antifúngicos y termiticidas, además de acción antioxidante, antibacteriana, antiartrítica, antiulcerosa, antiinflamatoria, miorelajante, antiviral y larvícida para *Aedes aegypti*. La diversidad fitoquímica de estas plantas y las diversas actividades biológicas ayudan a ampliar el conocimiento científico sobre estas especies, contribuyendo a la eventual producción de nuevos productos y/o nuevas tecnologías.

**Palabras clave:** Fabaceae; Plantas medicinales; *Hymenaea courbaril*; *Hymenaea stigonocarpa*; Compuestos fenólicos; Actividad biológica.

## 1. Introduction

Brazil has an extensive territorial area with about 8.5 million square kilometers (Ahmad et al., 2017) and is the country with the greatest biodiversity in the world with approximately 46.000 known plant species in the country, which are distributed in six terrestrial biomes (Amazon Forest, Pantanal, Cerrado, Caatinga, Pampa and Atlantic Forest) (Garcez et al., 2016; Lima et al., 2018). The rich Brazilian biodiversity is a source of resources for the country, not only for the ecosystem services provided, but also for the opportunities that represent its conservation, sustainable use and genetic heritage (Maranhão et al., 2013; Nahdi et al., 2020; Vieira et al., 2015).

The Fabaceae family is one of the largest and most important botanical families due to the large number of plant species used as a source of food, medicinal (Muthu et al., 2012), ornamental, timber and forage suppliers (Lacerda et al., 2014), fibers (Pluempunapat et al., 2013), dyes, gums, resins (Çam & Hişil, 2010) and oils (Luiz & Dinheiro, 2008). It is composed of 19,327 species distributed in 727 genera (Alves et al., 2019). This family consists of trees, shrubs, lianas and herbs, and has a cosmopolitan distribution (Bezerra-Silva et al., 2015). Brazil has about 2.827 species distributed in 222 genera, of which 1.524 species and 16 genera are endemic (Yadav et al., 2018).

Among its genera is *Hymenaea*, considered predominantly neotropical and consisting of a total of 16 species, of which 13 are found in Brazil (Dimech et al., 2013; Maranhão et al., 2013). The species of this genus of greater economic and medicinal importance in the North, Northeast, Midwest and Southeast of Brazil are *Hymenaea courbaril* and *Hymenaea stigonocarpa*, popularly known as “jatobás”, and are mainly found in cerrado vegetation (Oliveira et al., 2010; Veggi et al., 2014). These trees are widely used by the population in civil construction, ornamentation and mainly for curing or alleviating gastric, inflammatory, infectious and pulmonary diseases through their resin, fruit, sap, stem tea or stem bark (Bezerra-Silva et al., 2015; Maranhão et al., 2013; Santana et al., 2010).

Studies carried out with different parts (stem, roots and leaves) of *Hymenaea* species show that they have tannins, flavonoids, coumarins, amino acids and some carbohydrates in their composition (Oliveira de Veras et al., 2020; Oliveira et al., 2010; Veggi et al., 2014), which could explain the curative effects of this genus and its popular use (Boniface et al., 2017; Lacerda et al., 2014; Pinto et al., 2017).

Given the above, this study aims to identify in the literature biological activities associated with tannins and flavonoids present in the species *Hymenaea courbaril* and *Hymenaea stigonocarpa* through a systematic review, as these classes of compounds have outstanding antioxidant, antimicrobial, and gastroprotective activities, among others.

## 2. Methodology

### 2.1 Research strategy

The research methodology used to prepare this systematic review was based on the models proposed by Moura et al. (2015) (Moura et al., 2015), Kalalinia & Karimi-Sani (2017) (Kalalinia & Karimi-Sani, 2017), and Montana et al. (2019) (Montana et al., 2019), with modifications. The aim of this systematic review is associated with the biological activities of *H. courbaril* and *H. stigonocarpa* species related to tannins and flavonoids. The search for scientific articles was carried out considering publications available between the years 2009 to 2019 in the following databases: PubMed Central – PMC (<https://www.ncbi.nlm.nih.gov/pmc/>); Web of Science (<https://www.webofknowledge.com/>); Scopus ([https://www.scopus.com](https://www.scopus.com/)); and Science Direct (<https://www.sciencedirect.com>). The following keywords were used in order to develop an efficient search process for articles available in the scientific literature: *Hymenaea* AND flavonoids AND tannins AND medicinal plant.

### 2.2 Data selection

The review process began after conducting the research and extracting the articles from the databases, applying previously defined inclusion and exclusion criteria (Table 1).

**Table 1.** Inclusion and exclusion criteria.

Parameters	Inclusion	Exclusion
Publication type	Research articles	Literature reviews, encyclopedias, book chapters, conference abstracts, discussions, short communications, dissertations and theses
Study type	Studies that address biological activities associated with tannins and flavonoids present in different extracts or fractions obtained from species of the genus <i>Hymenaea</i> ;	Studies that do not show biological activities associated with flavonoids and/or tannins present in extracts or fractions obtained from <i>Hymenaea</i> species;
Language	English	Language other than English

Source: Prepared by the authors.

Titles and abstracts were subsequently evaluated, in addition to eliminating duplicates found in the databases. This was followed by a thorough reading of the chosen works, with the articles which were not within the scope of this work being eliminated. The bibliographical references of the selected articles were also analyzed in order to find possible works that could be included in this research.

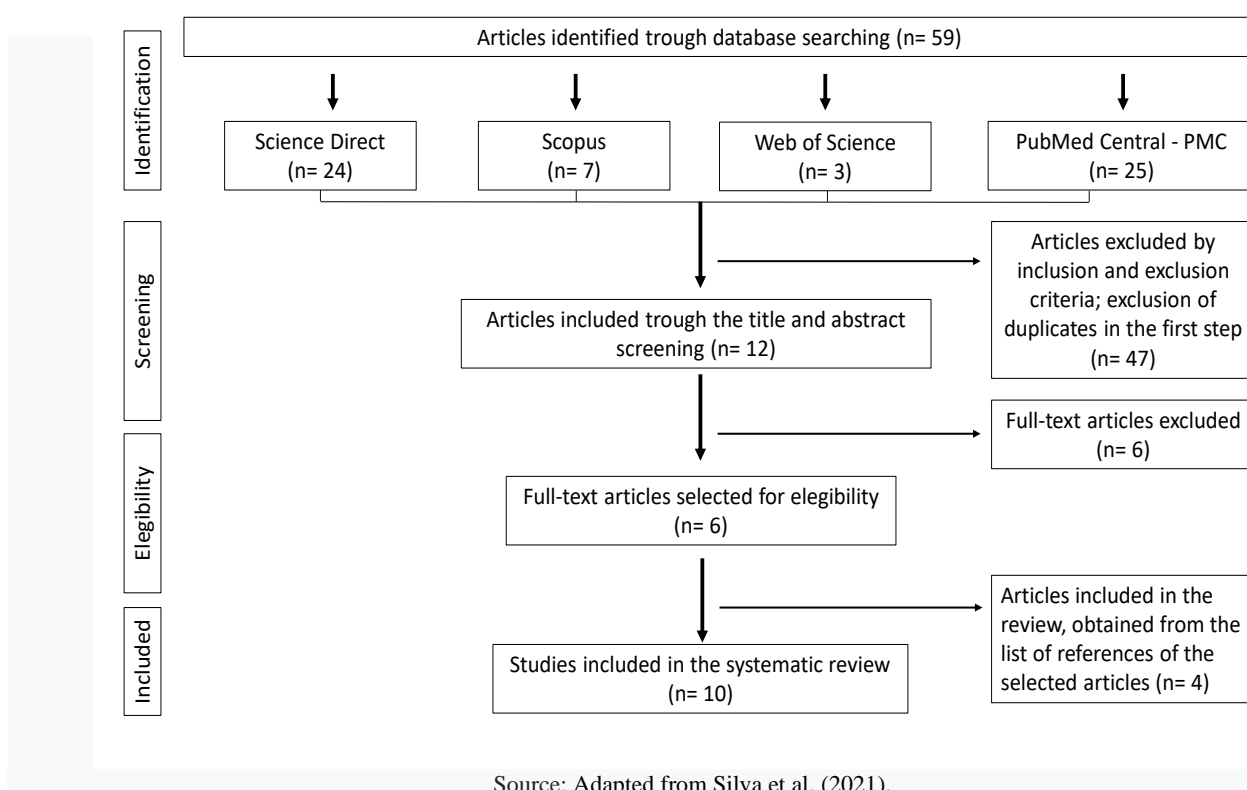
### 2.3 Data extraction

Based on reading the selected works, the information sought the following indicators: species, extraction methods, class of compounds present, isolated compounds and biological activities.

### 3. Results and Discussion

First, a total of 59 articles were found in the initial stage performed in the databases, but after reading the titles and abstracts according to the inclusion and exclusion criteria and eliminating repeated articles, 47 articles were discarded. Given the above, only 12 articles were used in the development of step 2. The texts were subsequently read in full and only 6 articles were used in the construction of the discussion. In addition, 4 articles obtained from the reference list of publications were added (Figure 1).

**Figure 1.** Flow diagram of the article selection process.



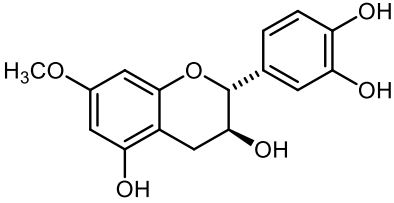
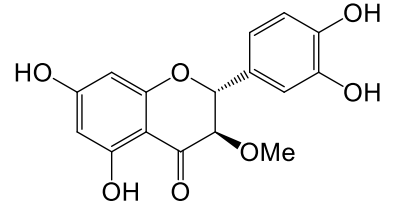
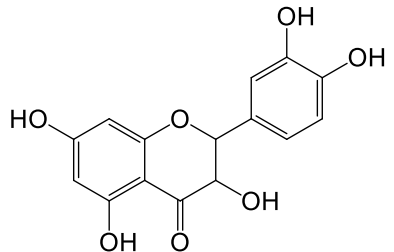
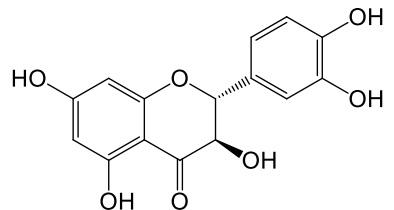
The ten articles selected after applying the methodological procedures were separated into different categories (Montana et al., 2019): Biological activities associated with *Hymenaea stigonocarpa* and *Hymenaea courbaril* (Table 2); Phytochemical compounds isolated from extracts and fractions from different parts of *Hymenaea stigonocarpa* and *Hymenaea courbaril* (Table 3).

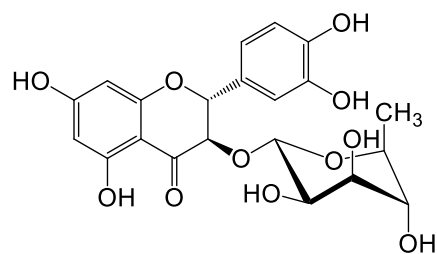
**Table 2.** Biological activities associated with *Hymenaea stigonocarpa* and *Hymenaea courbaril*.

Biological activities	Species	Parts of the plant used	Type of extract or fraction	Number of studies	References
Antioxidant	<i>H. stigonocarpa</i> e <i>H. courbaril</i>	Heartwood, stem bark, fruit pulp flour	Ethanol extract, methanol extract, ethyl acetate extract, ethyl acetate fraction and methanol fraction	7	(Bezerra et al., 2013; Dimech et al., 2013; Maranhão et al., 2013; Oliveira et al., 2010; Orsi et al., 2014; Rodrigues Orsi et al., 2012; Veggi et al., 2014)
Antimicrobial	<i>H. stigonocarpa</i>	Heartwood, stem bark	Ethanol extract, hydroalcoholic extract and aqueous fraction	2	(Dimech et al., 2013; Oliveira et al., 2010)
Antidiarrheal	<i>H. stigonocarpa</i>	Stem bark	Methanol extract	2	(Orsi et al., 2014; Rodrigues Orsi et al., 2012)
Gastroprotector	<i>H. stigonocarpa</i>	Stem bark	Methanol extract	1	(Rodrigues Orsi et al., 2012)
Intestinal anti-inflammatory	<i>H. stigonocarpa</i>	fruit pulp flour	Methanol extract	1	(Orsi et al., 2014)
Myorelaxant	<i>H. courbaril</i>	Stem bark	Ethanol extract	1	(Bezerra et al., 2013)
Antiviral	<i>H. courbaril</i>	Dehydrated leaves	Ethanol extract	1	(Cecílio et al., 2012)
Antithermitic	<i>H. stigonocarpa</i>	Heartwood	Ethyl acetate	1	(Santana et al., 2010)
Larvicide	<i>H. stigonocarpa</i>	Heartwood	Cyclohexane extract	1	(Bezerra-Silva et al., 2015)

Source: Prepared by the authors.

**Table 3.** Phytochemical compounds isolated from extracts and fractions from different parts of *Hymenaea stigonocarpa* and *Hymenaea courbaril*.

Structure	Nomenclature	Species	Used part	Type of extract or fraction	References
	7-methoxycathequin	<i>H. stigonocarpa</i>	Heartwood	Ethyl acetate extract	(Maranhão et al., 2013)
	Hultenin	<i>H. stigonocarpa</i>	Heartwood	Ethyl acetate extract	(Maranhão et al., 2013)
	Quercetin	<i>H. stigonocarpa</i>	Heartwood	Ethyl acetate extract	(Maranhão et al., 2013)
	Taxifolin	<i>H. stigonocarpa</i>	Heartwood	Ethyl acetate extract	(Maranhão et al., 2013)



Astilbine

*H. stigonocarpa*  
*H. courbaril*

Stem bark

Ethanol extracts,  
hydroalcoholic extract  
and aqueous fraction

(Bezerra et al., 2013;  
Dimech et al., 2013)

---

Source: Prepared by the authors.

### 3.1 Biological activities

Studies report that the *Hymenaea* genus mainly has tannins and flavonoids as major compounds in its phytochemical composition, however, other minor compounds are present in species of this genus, such as coumarins, amino acids and some carbohydrates (Oliveira de Veras et al., 2020; Oliveira et al., 2010). According to the studies found in this review, *H. stigonocarpa* and *H. courbaril* especially presented compounds belonging to the flavonoid and tannins class in their phytochemical composition (Bezerra-Silva et al., 2015; Maranhão et al., 2013; Veggi et al., 2014).

Biological activities such as antimicrobial, anti-inflammatory, antioxidant and antitermitic were found in studies with this genus (Bezerra-Silva et al., 2015; Bezerra et al., 2013; Dimech et al., 2013; Orsi et al., 2014; Rodrigues Orsi et al., 2012). According to some authors, such activities are directly related to the presence of flavonoids such as astilbine, taxifolin, hultenin, 7-methoxycathequin and quercetin isolated from extracts, powder and flour obtained from these species (Cecílio et al., 2012; Dimech et al., 2013; Maranhão et al., 2013).

However, other authors discuss that the anti-inflammatory, antitermitic and antimicrobial activities, in addition to being associated with the flavonoids present in *H. stigonocarpa*, are also directly linked to the presence of tannins present in this specie (Bezerra et al., 2013; Dimech et al., 2013; Maranhão et al., 2013).

#### 3.1.1 Antioxidant activity

The metabolic imbalance which often affects the body is associated with increased formation of free radicals, which promotes lipid peroxidation, characterized by a primary cytotoxicity that triggers a sequence of damage to cell membranes, which can cause flaccidity, lysis or apoptosis. Damage to DNA ribbons as well as collagen fibers and premature aging are also some effects caused by excess free radicals. Compounds with plant-based antioxidant activities are sought in a therapeutic or preventive way, since studies report that the action of natural antioxidants can inactivate these radicals and also repair the damage caused by them (Orsi et al., 2014; Rodrigues Orsi et al., 2012).

The mechanism by which antioxidant activity is triggered by plant extracts is complex, however, it is mainly attributed to the presence of phenolic compounds such as flavonoids, tannins and phenolic acids (Veggi et al., 2014). Such compounds play a fundamental role as an antioxidant due to the presence of aromatic hydroxyl groups, which eliminate free radicals through oxi-reduction reactions (Oliveira et al., 2010).

A species which has been gaining notoriety for presenting with antioxidant activity in some studies is *Hymenaea courbaril* L. var. *stilbocarpa* (Cecílio et al., 2012). Flavonoids and tannins with potential antioxidant action (C. Veggi et al., 2013; Martinez-Correa et al., 2012) were found in ethanol extracts obtained from its leaves, as presented in the study by Veggi et al., (2014). These authors identified the presence of tannins (1.8 mg/100 g of raw material) in *H. courbaril*, as well as the presence of procyanidins, both with antioxidant activity against the DPPH method, with an EC<sub>50</sub> of 0.2 mg/cm<sup>3</sup>.

Another study with *H. courbaril* using ethanol extract obtained from the stem bark, as well as ethyl acetate and methanol fractions, revealed the presence of flavonoids, tannins and anthocyanins. The presence of the flavonoid astilbine was identified in the ethyl acetate fraction. However, compared to the antioxidant activity analyzed by the DPPH method, both the ethanol extract and the ethyl acetate and methanol fractions showed expressive antioxidant activity with EC<sub>50</sub> of 3.07, 5.05 and 5.12 µg/mL, respectively (Bezerra et al., 2013).

The ethyl acetate extract obtained from the heartwood of *H. stigonocarpa* presented quercetin, 7-methoxycathequin, taxifolin and hultenin with antioxidant capacity in its composition according to the DPPH test, presenting an EC<sub>50</sub> of 9.95, 30, 78, 54.85, 61.65 and 78.80 µg/mL, respectively. Quercetin showed the best result among the isolated compounds when compared to other flavonoid molecules. However, it is noteworthy that ethyl acetate extract showed better results when



compared to the compounds alone. The study authors suggest that there is possibly a synergistic mechanism between the flavonoid molecules present in the extract, enhancing the antioxidant effect (Maranhão et al., 2013).

In another study, the methanol extract obtained from the heartwood of the *H. stigonocarpa* species also showed expressive antioxidant activity, with 91.00% of DPPH radical scavenging. The collaborators report that it was possible to observe the presence of phenolic compounds such as tannins and flavonoids in this extract, and to them, the antioxidant action verified in this study was linked (Oliveira et al., 2010).

*H. stigonocarpa* also showed antioxidant action which caused a decrease in lipid peroxidation against cell membranes in the brains of two-month-old male Wistar rats. In this study, the authors identified that the methanol extract of *H. stigonocarpa* (obtained from the stem bark) demonstrated *in vitro* EC<sub>50</sub> of 5.25 µg/mL. According to the authors, the result obtained may be linked to the presence of flavonoid compounds, as well as the presence of tannins with antioxidant capacities (Rodrigues Orsi et al., 2012).

Another study using *H. stigonocarpa* found that the methanol extract obtained from the pulp of its fruit also presented flavonoids and tannins with potential antioxidant activity, attenuating lipid peroxidation in the membranes of neural cells in Wistar rats in a dose-dependent manner. The *in vitro* antioxidant action for this evaluation demonstrated the EC<sub>50</sub> value of 27.33 µg/mL (Orsi et al., 2014).

All results obtained according to data found in scientific articles reinforce antioxidant action found in *H. courbaril* and *H. stigonocarpa*. These results demonstrate that these species have biotechnological potential for formulating products with therapeutic purposes for treating diseases such as cancer, diabetes, Parkinson's and Alzheimer's caused by oxidative stress (Rodrigues Orsi et al., 2012).

### **3.1.2 Antidiarrheal, gastroprotective, anti-inflammatory, myorelaxant and antiviral activities**

Biological activities associated with the species *H. courbaril* and *H. stigonocarpa* were evidenced in the literature, justifying the ethnopharmacological use of these plants. Studies report that species like these are promising in terms of maintaining human health through the treatment of various diseases (Bezerra-Silva et al., 2015; Orsi et al., 2014). These studies also mention that the biological activities associated with these species are correlated with the classes of major compounds which compose the phytochemistry of these plants, such as flavonoids and tannins (Bezerra-Silva et al., 2015; Oliveira et al., 2010).

Contributing to the above information, a study using methanol extract obtained from the stem bark of *H. stigonocarpa* at doses of 100, 150 and 200 mg/kg produced an antidiarrheal effect in mice with percentages of 61, 50 and 53%, respectively. In addition to this effect, the methanol extract also demonstrated gastroprotective effects at doses of 200 mg/kg. The authors report that this species has a promising profile for treating ulcers and digestive tract inflammation, however, other studies still need to be conducted (Rodrigues Orsi et al., 2012).

*H. stigonocarpa* also demonstrated anti-inflammatory effect from methanol extract (obtained from the fruit pulp flour). In this study, the authors report that mice which were treated with 10% of the methanol extract of *H. stigonocarpa*, in addition to having the intestinal inflammatory process attenuated, gained weight. The authors point out that the mice showed a significant reduction in the extent of the intestinal lesion at the dose of 100 mg/kg, as well as attenuation of diarrheal conditions. The methanol extract at the concentration of 200 mg/kg showed an effect of reducing adhesion to adjacent organs, as well as decreasing malondialdehyde levels. However, it was possible to observe inhibition of myeloperoxidase activity at the concentration of 400 mg/kg. It was also observed that there was depletion in the glutathione and alkaline phosphatase levels in the colon at doses of 100, 200 and 400 mg/kg, indicating anti-inflammatory activity. The authors report that the results found may be linked to the flavonoids and condensed tannins found in the methanol extract (Orsi et al., 2014).

*H. courbaril* also presented promising results in a study, showing expressive muscle relaxant activity from extracts and fractions obtained from the stem bark. The ethanol extract and the ethyl acetate fraction (obtained from the methanol extract) at concentrations of 1000 µg/mL produced a myorelaxant effect on the trachea of rats, decreasing the contraction of muscle tissue caused by carbachol and potassium chloride, with relaxation of 43.7% and 52.5% for the ethanol extract and 95.2 and 100% for the ethyl acetate fraction, respectively. The best result presented by the ethyl acetate fraction may be related to the presence of flavonoids that are the majority in products extracted with this organic solvent. corroborating this information, this study identified the flavonoid astilbine from the ethyl acetate fraction, which in isolation demonstrated a myorelaxant effect of 49.8% at a concentration of 1000 µg/mL. The authors also report that the ethyl acetate fraction showed myorelaxant effects of 46.98% at the concentration of 300 µg/mL. The authors suggest that these results may be mainly linked to astilbine, since it presented approximately half of the value shown by the fraction in isolation (Bezerra et al., 2013).

A reduction in the cytopathic effect against rotavirus (one of the main causes of diarrhea in children and infants) was also evidenced from 500 µg/mL of ethanolic extract of *H. courbaril* (obtained from dehydrated leaves). According to the authors, the decrease in cytopathic effect caused by rotavirus in the MA-104 cell line (rhesus monkey kidneys) was mainly associated with the presence of flavonoid compounds, as well as the existence of tannins in its composition. The researchers of this study also discuss that one of the possible mechanisms by which this effect occurred may be due to the complexation of proteins vital to replicating the rotavirus (Cecílio et al., 2012).

### 3.1.3 Antimicrobial activities

*H. stigonocarpa* extracts and fractions obtained from the bark of this species showed a bactericidal effect against *Staphylococcus aureus* (ATCC 33591), presenting minimum inhibitory concentration between 64 to 256 µg/mL. The bacteria showed structural changes after treatment, such as rupture of membranes and cell wall, leakage of materials into the cytoplasm, as well as molecular changes in nucleic acids, proteins and ribosomes. The authors also report that the presence of the flavonoid astilbine was identified in all samples, suggesting that it is the major compound present in the bark of *H. stigonocarpa* wood (Dimech et al., 2013).

A study using the milled heartwood of *H. stigonocarpa*, in addition to identifying the presence of flavonoids and tannins in its composition, also showed that this species presented natural resistance against the fungus *Phanerochaete chrysosporium*. In this study, the authors observed that the fungus, did not show mycelial growth when in contact with the ground heartwood of *H. stigonocarpa*. It is noteworthy that the microorganism used is one of those responsible for tree decay, degrading the main components of wood such as lignin and cellulose. According to the authors, the natural resistance presented by the milled heartwood of *H. stigonocarpa* may be mainly associated with the flavonoids found. These results suggest that *H. stigonocarpa* has antifungal potential, being able to treat plants with low durability to the attack of wood-reducing microorganisms (Oliveira et al., 2010).

### 3.1.4 Larvicide and antithermitic activities

Cyclohexane extract (obtained from *H. stigonocarpa* heartwood) at concentrations of 300 and 500 µg/mL showed larvicidal activity against *Aedes aegypti* mosquito larvae, the main vector of dengue, with 50% and 100% mortality of the larvae, respectively. The authors of this study report that the extract presented methoxylated flavonoids with possible larvicidal activities in its composition, which makes *H. stigonocarpa* a potential candidate to fight the dispersion of this dengue vector (Bezerra-Silva et al., 2015).

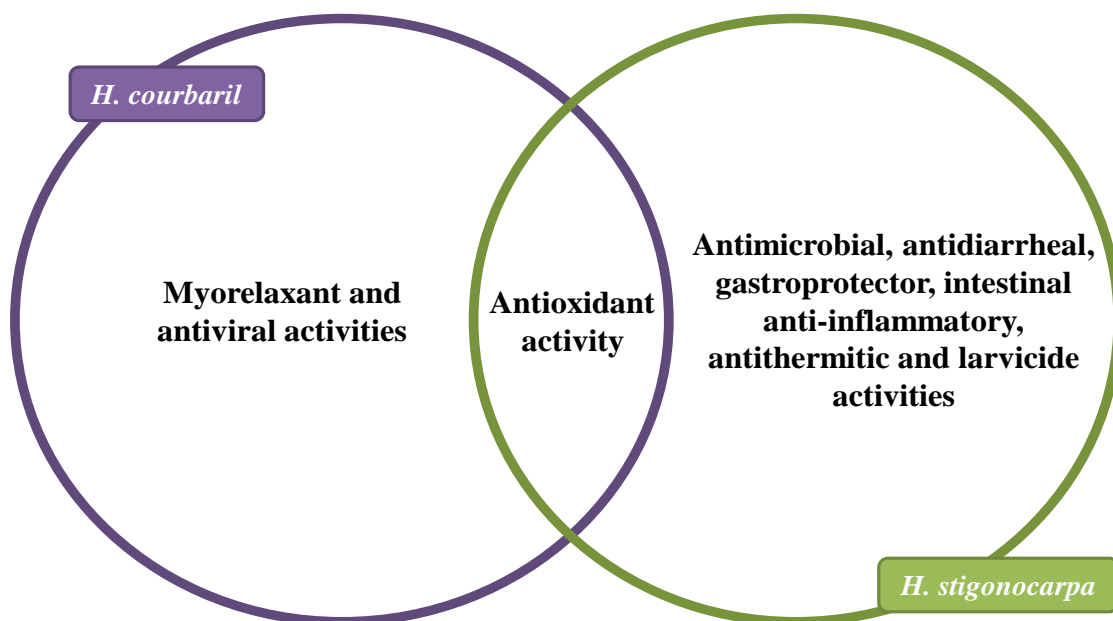
In addition to larvicidal activity, *H. stigonocarpa* also showed antithermitic activity through the cyclohexane extract (obtained from *H. stigonocarpa* heartwood) which was active against termites of the *Nasutitermes corniger* species, having

median lethal concentration of 11.9 mg/mL, in 4 days (Santana et al., 2010). The authors report that the activity presented in this study may be correlated with the presence of methoxylated flavonoids in the cyclohexane extract. These researchers also report that methoxylated flavonoids, in addition to having antioxidant activity, can also interfere with the digestion of lignocellulose in termites, which could be one of the reasons why termites would avoid these wood species.

The ethyl acetate extract (obtained from *H. stigonocarpa* heartwood) also showed anti-termite activity against *N. corniger* species. As a result, the extract at the concentration of 100 mg/mL caused 70% termite death within 5 days. The authors report that the data suggest that the presence of four flavonoids (hultenin, taxifolin, quercetin and 7-methoxycathequin) in the composition of this extract was correlated with antithermitic activity. It is noteworthy that quercetin in isolation also demonstrated anti-termite activity, with 55% of termite death within 5 days. According to the researchers, no significant differences were detected between hultenin, taxifolin and 7-methoxycathequin for the outcome of termite death, which could lead to the understanding that quercetin may be the main flavonoid responsible for the antithermitic activity of the ethyl acetate extract of *H. stigonocarpa* (Maranhão et al., 2013).

The scarcity of studies involving *H. courbaril* and *H. stigonocarpa* is observed, in addition to the lack of phytochemical characterization of these species. being even more evident the lack of records of biological activities attributed to *H. courbaril* as illustrated in Figure 2.

**Figure 2.** Biological activities associated with *H. courbaril* and *H. stigonocarpa*.



Source: Prepared by the authors.

#### 4. Conclusion

In this review, it was possible to observe the biological activity presented by the species *H. courbaril* and *H. stigonocarpa*, with emphasis on flavonoids and tannins. Based on the number of articles available in the scientific literature, it can be observed that phytochemical studies with these plant species are scarce. Only the heartwood constituents of *H. stigonocarpa* have been studied with respect to their activity against xylophagous organisms (white-rot fungi and termites).

The results make these constituents candidates for use in the manufacture of products to combat biodegradation caused by either fungi or termites.

Thus, from the information presented on the species *H. courbaril* and *H. stigonocarpa*, it is possible to observe that they have economic and medicinal importance, however, very few has been explored. For this reason, further studies are needed to better understand the biological activity of these species.

## Acknowledgments

The authors are grateful the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)

## Author Contributions

All the authors contributed equally, in all stages, in the accomplishment of this work. All authors have read and agreed to the published version of the manuscript.

## Conflict of Interest

The authors declare that there are no conflicts of interest

## References

- Ahmad, A., Tandon, S., Dang, T., & Nooreen, Z. (2017). ScienceDirect A Review on Phytoconstituents and Biological activities of Cuscuta species. *Biomedicine et Pharmacotherapy*, 92, 772–795. <https://doi.org/10.1016/j.biopha.2017.05.124>
- Alves, K., Oliveira, D., Diana, M., Gomes, M., Prado, R., Sousa, E., Abreu, D., Soares, R., César, A., Loureiro, C., Coelho-de-souza, A. N., Sombra, R., & Oliveira, B. De. (2019). Biomedicine & Pharmacotherapy Phytomodulatory proteins promote inhibition of hepatic glucose production and favor glyceemic control via the AMPK pathway. *Biomedicine & Pharmacotherapy*, 109, 2342–2347. <https://doi.org/10.1016/j.biopha.2018.11.139>
- Bezerra-Silva, P. C., Santos, J. C., Santos, G. K. N., Dutra, K. A., Santana, A. L. B. D., Maranhão, C. A., Nascimento, M. S., Navarro, D. M. A. F., & Bieber, L. W. (2015). Extract of Bowdichia virgilioides and maackiain as larvicidal agent against Aedes aegypti mosquito. *Experimental Parasitology*, 153, 160–164. <https://doi.org/10.1016/j.exppara.2015.03.018>
- Bezerra, G. P., Góis, R. W. D. S., Brito, T. S. De, Lima, F. J. B. De, Bandeira, M. A. M., Romero, N. R., Magalhães, P. J. C., & Santiago, G. M. P. (2013). Phytochemical study guided by the myorelaxant activity of the crude extract, fractions and constituent from stem bark of Hymenaea courbaril L. *Journal of Ethnopharmacology*, 149 (1), 62–69. <https://doi.org/10.1016/j.jep.2013.05.052>
- Boniface, P. K., Baptista Ferreira, S., & Roland Kaiser, C. (2017). Current state of knowledge on the traditional uses, phytochemistry, and pharmacology of the genus Hymenaea. *Journal of Ethnopharmacology*, 206, 193–223. <https://doi.org/10.1016/j.jep.2017.05.024>
- C. Veggi, P., T. Santos, D., Fabiano-Tixier, A.-S., Le Bourvellec, C., Angela A. Meireles, M., & Chemat, F. (2013). Extraction of Polyphenols and Anthocyanins from the Jambul (Syzgium cumini) Fruit Peels. *Food and Public Health*, 3 (3), 119–129. <https://doi.org/10.5923/j.fph.20130303.02>
- Çam, M., & Hişil, Y. (2010). Pressurised water extraction of polyphenols from pomegranate peels. *Food Chemistry*, 123(3), 878–885. <https://doi.org/10.1016/j.foodchem.2010.05.011>
- Cecílio, A. B., Faria, D. B. De, Oliveira, P. D. C., Caldas, S., Oliveira, D. A. De, Sobral, M. E. G., Duarte, M. G. R., Moreira, C. P. D. S., Silva, C. G., & Almeida, V. L. De. (2012). Screening of Brazilian medicinal plants for antiviral activity against rotavirus. *Journal of Ethnopharmacology*, 141 (3), 975–981. <https://doi.org/10.1016/j.jep.2012.03.031>
- Dimech, G. S., Soares, L. A. L., Ferreira, M. A., De Oliveira, A. G. V., Carvalho, M. D. C., & Ximenes, E. A. (2013). Phytochemical and antibacterial investigations of the extracts and fractions from the stem bark of Hymenaea stigonocarpa Mart. ex Hayne and effect on ultrastructure of Staphylococcus aureus induced by hydroalcoholic extract. *The Scientific World Journal*. <https://doi.org/10.1155/2013/862763>
- Garcez, F. R., Garcez, W. S., Yoshida, N. C., & Figueiredo, P. O. (2016). The chemical diversity from the vegetation of Mato Grosso do Sul and its relevance as a source of bioactive molecules. *Revista Virtual de Química*, 8 (1), 97–129. <https://doi.org/10.5935/1984-6835.20160008>
- Kalalinia, F., & Karimi-Sani, I. (2017). Anticancer Properties of Solamargine: A Systematic Review. In *Phytotherapy Research* (Vol. 31, Issue 6, pp. 858–870). <https://doi.org/10.1002/ptr.5809>
- Lacerda, L. P., Malaquias, G., & Peron, A. P. (2014). Antiproliferative action of aqueous extracts of Hymenaea stigonocarpa Mart. (Fabaceae) on the cell cycle of Allium cepa L. *Anais Da Academia Brasileira de Ciencias*, 86 (3), 1147–1150. <https://doi.org/10.1590/0001-3765201420130163>
- Lima, N. M., Cursino-Hron, L. M., Lima, A. M., Souza, J. V. B., de Oliveira, A. C., Marinho, J. V. N., & Nunez, C. V. (2018). Antifungal activity of extracts and phenolic compounds from Deguelia duckeana. *Revista Brasileira de Farmacognosia*, 28 (6), 697–702. <https://doi.org/10.1016/j.bjp.2018.08.004>

- Luiz, A., & Dinheiro, B. C. (2008). *Plantas medicinais de um remascente de Floresta Ombrófila Mista Altomontana, Urupema, Santa Catarina, Brasil*. 380–397.
- Maranhão, C. A., Pinheiro, I. O., Santana, A. L. B. D., Oliveira, L. S., Nascimento, M. S., & Bieber, L. W. (2013). Antitermitic and antioxidant activities of heartwood extracts and main flavonoids of *Hymenaea stigonocarpa* Mart. *International Biodeterioration and Biodegradation*, 79, 9–13. <https://doi.org/10.1016/j.ibiod.2013.01.005>
- Martinez-Correa, H. A., Cabral, F. A., Magalhães, P. M., Queiroga, C. L., Godoy, A. T., Sánchez-Camargo, A. P., & Paviani, L. C. (2012). Extracts from the leaves of *Baccharis dracunculifolia* obtained by a combination of extraction processes with supercritical CO<sub>2</sub>, ethanol and water. *Journal of Supercritical Fluids*, 63, 31–39. <https://doi.org/10.1016/j.supflu.2011.12.016>
- Montana, M., Mathias, F., Terme, T., & Vanelle, P. (2019). Antitumor activity of quinoxaline derivatives: A systematic review. In *European Journal of Medicinal Chemistry*, 163, 136–147. Elsevier Masson SAS. <https://doi.org/10.1016/j.ejmech.2018.11.059>
- Moura, F. A., de Andrade, K. Q., dos Santos, J. C. F., Araújo, O. R. P., & Goulart, M. O. F. (2015). Antioxidant therapy for treatment of inflammatory bowel disease: Does it work? In *Redox Biology*, 6, 617–639. <https://doi.org/10.1016/j.redox.2015.10.006>
- Muthu, C., Reagan, A. D., Kingsley, S., & Ignacimuthu, S. (2012). Larvicidal activity of pectolinarigenin from *Clerodendrum phlomidis* L. against *Culex quinquefasciatus* Say and *Aedes aegypti* L. (Diptera: Culicidae). *Parasitology Research*, 111 (3), 1059–1065. <https://doi.org/10.1007/s00436-012-2932-8>
- Nahdi, A., Hammami, I., Ben, R., Kallech-ziri, O., El, A., Véronique, M., & May, E. (2020). Biomedicine & Pharmacotherapy Effect of *Hypericum humifusum* aqueous and methanolic leaf extracts on biochemical and histological parameters in adult rats. *Biomedicine & Pharmacotherapy*, 108, 144–152. <https://doi.org/10.1016/j.biopha.2018.09.034>
- Oliveira de Veras, B., Melo de Oliveira, M. B., Granja da Silva Oliveira, F., Queiroz dos Santos, Y., Saturnino de Oliveira, J. R., Lúcia de Menezes Lima, V., Guedes da Silva Almeida, J. R., Maria do Amaral Ferraz Navarro, D., Ribeiro de Oliveira Farias de Aguiar, J. C., Aguiar, J. dos S., Gorchach-Lira, K., Dias de Assis, C. R., Vanusa da Silva, M., & Catarina de Souza Lopes, A. (2020). Chemical composition and evaluation of the antinociceptive, antioxidant and antimicrobial effects of essential oil from *Hymenaea cangaceira* (Pinto, Mansano & Azevedo) native to Brazil: A natural medicine. *Journal of Ethnopharmacology*, 247, 112265. <https://doi.org/10.1016/j.jep.2019.112265>
- Oliveira, L. S., Santana, A. L. B. D., Maranhão, C. A., de Miranda, R. D. C. M., Galvão de Lima, V. L. A., da Silva, S. I., Nascimento, M. S., & Bieber, L. (2010). Natural resistance of five woods to *Phanerochaete chrysosporium* degradation. *International Biodeterioration and Biodegradation*, 64 (8), 711–715. <https://doi.org/10.1016/j.ibiod.2010.08.001>
- Orsi, P. R., Seito, L. N., & Di Stasi, L. C. (2014). *Hymenaea stigonocarpa* Mart. ex Hayne: A tropical medicinal plant with intestinal anti-inflammatory activity in TNBS model of intestinal inflammation in rats. *Journal of Ethnopharmacology*, 151 (1), 380–385. <https://doi.org/10.1016/j.jep.2013.10.056>
- Pinto, R. B., de Freitas Mansano, V., Torke, B. M., & de Azevedo Tozzi, A. M. G. (2017). On the “Cangaço” route: a new species of *Hymenaea* (Leguminosae) from the Brazilian Caatinga. *Kew Bulletin*, 72 (3). <https://doi.org/10.1007/s12225-017-9713-6>
- Pluempunapat, S., Kumrungsee, N., Pluempunapat, W., Ngamkitpinyo, K., Chavasiri, W., Bullangpoti, V., & Koul, O. (2013). Laboratory evaluation of *Dalbergia oliveri* (Fabaceae: Fabales) extracts and isolated isoflavonoids on *Aedes aegypti* (Diptera: Culicidae) mosquitoes. *Industrial Crops and Products*, 44, 653–658. <https://doi.org/10.1016/j.indcrop.2012.09.006>
- Rodrigues Orsi, P., Bonamin, F., Aparecida Severi, J., Cássia Santos, R., Vilegas, W., Hiruma-Lima, C. A., & Stasi, L. C. Di. (2012). *Hymenaea stigonocarpa* Mart. ex Hayne: A Brazilian medicinal plant with gastric and duodenal anti-ulcer and antidiarrheal effects in experimental rodent models. *Journal of Ethnopharmacology*, 143 (1), 81–90. <https://doi.org/10.1016/j.jep.2012.06.001>
- Santana, A. L. B. D., Maranhão, C. A., Santos, J. C., Cunha, F. M., Conceição, G. M., Bieber, L. W., & Nascimento, M. S. (2010). Antitermitic activity of extracts from three Brazilian hardwoods against *Nasutitermes corniger*. *International Biodeterioration and Biodegradation*, 64 (1), 7–12. <https://doi.org/10.1016/j.ibiod.2009.07.009>
- Silva, B. I. M., Nascimento, E. A., Silva, C. J., Silva, T. G., & Aguiar, J. S. (2021). Anticancer activity of monoterpenes: a systematic review. *Molecular Biology Reports*, 0123456789. <https://doi.org/10.1007/s11033-021-06578-5>
- Veggi, P. C., Prado, J. M., Bataglioni, G. A., Eberlin, M. N., & Meireles, M. A. A. (2014). Obtaining phenolic compounds from jatoba (*Hymenaea courbaril* L.) bark by supercritical fluid extraction. *Journal of Supercritical Fluids*, 89, 68–77. <https://doi.org/10.1016/j.supflu.2014.02.016>
- Vieira, L. S., Sousa, R. S., & Lemos, J. R. (2015). Plantas medicinais conhecidas por especialistas locais de uma comunidade rural maranhense. *Revista Brasileira de Plantas Medicinais*, 17 (4), 1061–1068. [https://doi.org/10.1590/1983-084X/15\\_009](https://doi.org/10.1590/1983-084X/15_009)
- Yadav, E., Singh, D., Yadav, P., & Verma, A. (2018). Biomedicine & Pharmacotherapy Antioxidant and anti-inflammatory properties of *Prosopis cineraria* based phenolic rich ointment in wound healing. *Biomedicine & Pharmacotherapy*, 108, 1572–1583. <https://doi.org/10.1016/j.biopha.2018.09.180>