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PHYTOCHEMICAL PROFILE, PHENOLIC AND FLAVONOID CONTENT, AND ANTIFUNGAL ACTIVITY OF THE RESINOUS EXTRACT OF PROTIUM SPRUCEANUM (BENTH.) ENGLER

PERFIL FITOQUÍMICO, TEOR DE FENÓLICOS E FLAVONOIDES E ATIVIDADE ANTIFÚNGICA DO EXTRATO RESINOSO DE PROTIUM SPRUCEANUM (BENTH.) ENGLER

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ABSTRACT

This study aimed to identify the major phytochemical groups of specialized metabolism, determine the total phenolic and flavonoid contents, and evaluate the *in vitro* antifungal activity of *Protium spruceanum* oleoresin against phytopathogenic fungi associated with agricultural deterioration. The hydroethanolic resin extract was obtained by maceration, and qualitative and quantitative phytochemical analyses were performed using standard colorimetric methods. Antifungal potential was evaluated using the agar diffusion method against *Aspergillus flavus*, *Aspergillus niger*, *Colletotrichum gloeosporioides*, *Colletotrichum acutatum*, and *Sclerotinia sclerotiorum* at concentrations of 10%, 50%, 80%, and 100%. Phytochemical screening revealed the presence of phenolic compounds, flavonoids, alkaloids, saponins, tannins, and steroids. Total phenolic and flavonoid contents were quantified at 68.3 mg GAE g^{-1} and 20.7 mg QE g^{-1}, respectively. In the antifungal assays, the extract exhibited significant, concentration-dependent inhibitory effects against all tested strains, with the 100% concentration achieving the highest mycelial growth inhibition, particularly against *C. gloeosporioides* 30.39% and *S. sclerotiorum* 24.03%. Although the extract showed lower efficacy than the commercial synthetic fungicide, its considerable bioactive compound content and inhibitory activity indicate that *Protium spruceanum* resin represents a promising natural alternative for integrated management strategies in agricultural protection.

Keywords: *Protium* genus; resin extract; phytochemical profile; total phenolic and flavonoid contents; antifungal activity.

RESUMO

Este estudo teve como objetivo identificar os principais grupos fitoquímicos do metabolismo especializado, determinar os teores de

fenólicos e flavonoides totais e avaliar a atividade antifúngica *in vitro* da oleoresina de *Protium spruceanum* contra fungos fitopatogênicos associados à deterioração agrícola. O extrato resinoso hidroetanólico foi obtido por maceração, e as análises fitoquímicas qualitativas e quantitativas foram realizadas por meio de métodos colorimétricos padrão. O potencial antifúngico foi avaliado pelo método de difusão em ágar contra *Aspergillus flavus*, *Aspergillus niger*, *Colletotrichum gloeosporioides*, *Colletotrichum acutatum* e *Sclerotinia sclerotiorum* nas concentrações de 10%, 50%, 80% e 100%. A triagem fitoquímica revelou a presença de compostos fenólicos, flavonoides, alcaloides, saponinas, taninos e esteroides. Os teores de fenólicos e flavonoides totais foram quantificados em 68,3 mg EAG g^{-1} e 20,7 mg EQ g^{-1}, respectivamente. Nos ensaios antifúngicos, o extrato apresentou efeitos inibitórios significativos e dependentes da concentração sobre todas as cepas testadas, sendo que a concentração de 100% alcançou a maior inibição do crescimento micelial, com destaque para *C. gloeosporioides* com 30,39% e *S. sclerotiorum* com 24,03%. Embora o extrato tenha apresentado eficácia inferior ao fungicida sintético comercial, seu notável teor bioativo e sua atividade inibitória indicam que a resina de *Protium spruceanum* representa uma alternativa natural promissora para estratégias de manejo integrado na proteção agrícola.

Palavras-chave: *Protium*; extrato resinoso; perfil fitoquímico; fenólicos e flavonoides totais; atividade antifúngica.

1. INTRODUCTION

The Burseraceae family comprises predominantly tropical plant species characterized by the production of resinous exudates and oleoresins with diverse chemical compositions and biological

potential (Menezes Filho *et al.*, 2022). Within this family, the genus *Protium* Burm. f. stands out for its diversity in the Neotropical region, particularly in Brazil, where approximately 84 species have been recorded, including 18 endemic species (Silva; Sakuragui, 2024).

These plants have ecological, economic, and ethnobotanical importance, mainly due to the production of aromatic resins traditionally used in folk medicine and other applications. Their chemical composition, particularly the presence of terpenoids, triterpenoids, and phenolic compounds, has attracted scientific interest because of their antioxidant, antimicrobial, anti-inflammatory, and antifungal properties (Amparo *et al.*, 2020; Amparo *et al.*, 2022).

Among the species of this genus, *Protium spruceanum* (Benth.) Engl. has attracted attention because of its resin production and phytochemical potential. Bruzinga *et al.* (2022) identified pentacyclic triterpenoids as major constituents of its resin, particularly α-amyrin, β-amyrin, α-amyrone, and β-amyrone. Furthermore, Menezes Filho *et al.* (2021) reported different phytochemical groups and antioxidant and antibacterial activities in the hydroethanolic resin extract. These findings demonstrate the biological potential of the species and support further investigations into its chemical composition and other biological properties.

Phenolic compounds and flavonoids are important specialized metabolites associated with plant defense and antioxidant and antimicrobial activities. Their quantification is widely used in phytochemical characterization and may help establish relationships between chemical composition and biological properties. Veloso & Lacerda (2025), investigating an ethyl acetate extract of *P.*

spruceanum, reported 302.35 mg gallic acid equivalents g^{-1} of total phenolics, as well as flavonoid contents of 88.58 mg rutin equivalents g^{-1} and 59.74 mg quercetin equivalents g^{-1}. These results reinforce the importance of investigating the phenolic and flavonoid composition of different preparations of this species, particularly its resinous fraction.

The search for natural antifungal substances has become increasingly relevant to agriculture because of the economic losses caused by phytopathogenic and seed- and grain-deteriorating fungi. Among the most important species are *Sclerotinia sclerotiorum*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Colletotrichum gloeosporioides*, and *Colletotrichum acutatum*, which are associated with plant diseases, contamination, and deterioration of agricultural products (Ashokkumar *et al.*, 2026; Hossain *et al.*, 2023; Peralta-Ruiz *et al.*, 2023; Sharma *et al.*, 2023). In particular, *A. flavus* is noteworthy for its ability to produce aflatoxins (Gong *et al.*, 2024), whereas *S. sclerotiorum* causes white mold in several economically important crops (Shang *et al.*, 2024). Likewise, species of *Colletotrichum* are responsible for anthracnose, affecting different plant organs and compromising crop quality (Law *et al.*, 2025).

Recent studies have demonstrated the antifungal potential of plant-derived compounds against these microorganisms (Bandeira *et al.*, 2026; Carvajal *et al.*, 2015; de Lima *et al.*, 2022). Essential oils and their constituents have shown inhibitory effects against *S. sclerotiorum* (Dias *et al.*, 2020; Fontana *et al.*, 2020), *A. flavus* (Abdel Gwad *et al.*, 2024; Duan *et al.*, 2024), *C. acutatum* (Morkeliūnė *et al.*, 2021), and *C. gloeosporioides* (Yuan *et al.*, 2024). These effects may be associated with the presence of bioactive compounds capable of interfering with fungal cell membranes, enzymatic activity, and metabolic

processes, thereby limiting mycelial development (Rodrigues *et al.*, 2023). In this context, plant extracts and oleoresins represent promising sources of natural substances for developing complementary strategies to conventional agricultural disease management.

Despite the phytochemical and biological potential already reported for *P. spruceanum*, information regarding the antifungal activity of its oleoresin against agriculturally relevant fungi remains limited. Therefore, investigating its phytochemical composition, total phenolic and flavonoid contents, and antifungal effects may contribute to a better understanding of its biological potential and support future applications in the protection and preservation of agricultural products.

This study aimed to identify the main phytochemical groups of specialized metabolism, determine the total phenolic and flavonoid contents, and evaluate the antifungal activity of *Protium spruceanum* oleoresin against groups of fungi associated with agricultural deterioration.

2. METHODS

2.1. Collection And Botanical Identification

Approximately 250 g of *P. spruceanum* resin were collected from 12 individual trees located in a gallery forest area on a farm in the municipality of Rio Verde, Goiás, Brazil, in June 2026. The resin was collected from the tree trunks at the end of the day, between 6:00 and 8:00 p.m. The collection site is geographically located at 17°43'10.5"S and 50°53'06.9"W, at an average altitude of 748 m above sea level. The region has a tropical climate, according to the Köppen–

Geiger climate classification (*Aw*) (Lima *et al.*, 2023), also characterized as tropical humid or semi-humid, with two well-defined seasons. A herbarium specimen was prepared, identified, and deposited at the Herbarium of the UniBRAS University Center of Rio Verde, Goiás, Brazil, under voucher number BRAS 10121.

2.2. Preparation Of The Hydroethanolic Extract

The crude plant extract was prepared using the maceration extraction method. Approximately 150 g of powdered plant material, previously ground in a processor, was weighed using an analytical balance (Weblaborsp, Model M214AI, Brazil), transferred to a 500 mL Erlenmeyer flask, and subjected to extraction with 200 mL of an 80% (*w/v*) hydroethanolic solution.

The maceration process was carried out for 48 h. Subsequently, the extract was transferred to a funnel containing qualitative filter paper (Whatman® n° 1) (Unifil, Brazil), and the supernatant was collected in a 300 mL Beaker. The extract was then concentrated using a rotary evaporator under reduced pressure until complete evaporation of the ethanol solvent, leaving only the crude aqueous extract. The aqueous extract was stored under refrigeration at 4 °C for subsequent phytochemical and microbiological analyses.

For the quantitative determination of total phenolic and flavonoid contents, a second sample of the hydroethanolic extract was prepared under the same conditions described above. However, the resulting aqueous extract was frozen at −10 °C and subsequently lyophilized using a freeze dryer (Lotec, Model L101, Brazil). After lyophilization, the extract was ground into a fine powder and stored

under refrigeration at 4 °C until analysis, following the methodology adapted from Yadav & Agarwala (2011).

2.3. Qualitative Phytochemical Profile

The extract was screened for the presence of bioactive compounds using standard qualitative phytochemical methods to detect proteins, lipids, phenolic compounds, flavonoids, alkaloids, anthocyanins, diterpenes, saponins, carbohydrates, resins, tannins, cardiac glycosides, steroids, organic acids, coumarins, reducing and non-reducing sugars, anthraquinones, catechins, depsides, depsidones, amino acids, purines, and terpenoids, as described by Yadav & Agarwala (2011) and Ferreira *et al.* (2023).

2.4. Quantitative Phytochemical Analysis

2.4.1. Total Phenolic Content

The total phenolic content of the lyophilized aqueous extract was determined using the *Folin–Ciocalteu* colorimetric method, as described by Aiyegroro & Okoh (2010), with modifications. Briefly, 2.5 mL of 10% (*v/V*) *Folin–Ciocalteu* reagent, 2.0 mL of 2% (*w/V*) aqueous sodium carbonate (Na_2CO_3) solution, and 1.0 mL of the plant extract solution were added to test tubes. The resulting mixture was incubated at room temperature for 15 min. Subsequently, the absorbance was measured at 765 nm using a UV–*Vis* spectrophotometer (BelPhotonics, Model M-51, Italy).

Gallic acid was used as the analytical reference standard at a concentration of 1 mg mL^{-1} to construct the calibration curve, which presented a coefficient of determination (R^2) of 0.991. All analyses

were performed in triplicate. Total phenolic content was calculated based on the gallic acid calibration curve and expressed as milligrams of gallic acid equivalents per gram of dry extract (mg GAE g^{-1}).

2.4.2. Total Flavonoid Content

The total flavonoid content of the lyophilized aqueous extract was determined using the aluminum chloride colorimetric method, as described by Aiyegroro & Okoh (2010), with modifications. Briefly, 1.0 mL of the aqueous plant extract solution was added to 3.0 mL of methanol (PA-ACS, Anidrol, Brazil), followed by 0.2 mL of 10% (*w/V*) aqueous aluminum chloride ($AlCl_3$) solution, 0.2 mL of 1 M aqueous potassium acetate solution, and 5.6 mL of distilled water. The resulting mixture was homogenized and incubated at room temperature for 30 min in the dark.

After incubation, the absorbance was measured at 420 nm using a UV–*Vis* spectrophotometer. Quercetin was used as the analytical reference standard at a concentration of 1 mg mL^{-1} to construct the calibration curve, which presented a coefficient of determination (R^2) of 0.994. All analyses were performed in triplicate. Total flavonoid content was calculated based on the quercetin calibration curve and expressed as milligrams of quercetin equivalents per gram of dry extract (mg QE g^{-1}).

2.5. *In Vitro* Antifungal Assay

The antifungal activity of the crude plant extract against *A. flavus*, *A. niger*, *C. gloeosporioides*, *C. acutatum*, and *S. sclerotiorum* was evaluated using the agar diffusion method, according to Haab *et al.*

(2026), with modifications. The fungal strains used in this study were AF-321, AF-323, CG-100, CA-007, and SS-21, respectively, obtained from the mycological collection maintained by the fourth author. Before the assays, the fungal strains were cultivated at 20 °C for 10 days for *S. sclerotiorum* and at 28 °C for 3–5 days for the other fungal species.

For the antifungal assays, 10-cm-diameter *Petri* dishes containing sterile potato dextrose agar (PDA) medium (Kasvi, Spain) were used. The crude plant extract was prepared at four concentrations (10, 50, 80, and 100%), using dimethyl sulfoxide (DMSO) (PA-ACS, Synth, India) at 0.5% as the solvent. Subsequently, 500 µL of each respective extract concentration was applied to the surface of the culture medium. After application of the extract, a 7-mm-diameter mycelial disc was aseptically placed in the center of each *Petri* dish.

The inoculated plates were incubated at 20 °C for 10 days for *S. sclerotiorum* and at 28 °C for 3–5 days for the remaining fungal species. Mycelial growth was monitored daily until the fungi completely colonized the culture medium in the negative control plates. Antifungal activity was assessed by measuring the diameter of the inhibition zone (mm) using a digital caliper. The measurements were subsequently converted into percentage values to express the antifungal activity of the extracts.

The commercial fungicide Frowncide 500® SC was used as a positive control at a concentration of 70% (*v/v*), diluted in distilled and autoclaved water. The negative control consisted of PDA medium without the addition of plant extract or DMSO. Additionally, DMSO was evaluated separately at the lowest tested concentration (10%, *v/v*) to assess its potential influence on fungal growth. All assays were

performed in quadruplicate, following a completely randomized experimental design.

2.6. Statistical Data Analysis

The data were subjected to analysis of variance (ANOVA), and, when significant differences among treatments were detected, means were compared using *Tukey's* test at a 5% probability level ($p \leq 0.05$).

3. RESULTS

The qualitative phytochemical profile of the hydroethanolic resin extract of *P. spruceanum* is presented in (Table 1). The analysis revealed the presence of several phytochemical constituents with potential biological activities of interest for agricultural applications, including phenolic compounds, flavonoids, alkaloids, saponins, resins, tannins, steroids, organic acids, non-reducing sugars, catechins, and amino acids.

Table 1. Phytochemical constituents identified in *Protium spruceanum* resin.

Phytochemical Tests	Resin Extract
Proteins	-
Lipids	-
Phenolics	+
Flavonoids	+
Alkaloids	+
Anthocyanins	-

Diterpenes	-
Saponins	+
Carbohydrates	-
Resins	+
Tannins	+
Cardiac glycosides	-
Steroids	+
Organic acids	+
Coumarins	-
Reducing sugars	-
Non-reducing sugars	+
Anthraquinones	-
Catechins	+
Depsides	-
Depsidones	-
Amino acids	+
Purines	-
Terpenoids	-

Note: (+) presence; (-) absence of a colorimetric reaction or formation of clumps or sediment. Source: Authors, 2026.

The total phenolic and flavonoid contents in the resin extract of *P. spruceanum* were 68.3 mg g^{-1} and 20.7 mg g^{-1}, respectively. Regarding the in vitro antifungal assay, the extract demonstrated

significant inhibitory effects against all evaluated phytopathogenic strains in a concentration-dependent manner (Table 2).

Across all species, the 100% extract concentration achieved the highest mean mycelial inhibition, peaking against *C. gloeosporioides* 30.39% and *S. sclerotiorum* 24.03%. Conversely, the lowest concentration (10%) exhibited minimal efficacy, with complete absence of inhibition 0.00% recorded for *A. niger*, *C. gloeosporioides*, and *C. acutatum*. Although the extract's antifungal activity increased proportionally with concentration, all tested concentrations resulted in significantly lower mycelial inhibition than the commercial chemical fungicide used as a positive control.

Table 2. Antifungal activity of *Protium spruceanum* resin extract at different concentrations.

Strains	Inhibition Concentration (%)*				Standa fungic Frown 500 S
	10%	50%	80%	100%	70%
A. flavus	3.40e	10.03d	13.90c	18.38b	100
A. niger	0.00e	6.83d	11.90c	19.08b	100
C.	0.00e	16.79d	21.62c	30.39b	100

⚠ Esta tabela possui muitas colunas e foi cortada para impressão. Para visualizá-la completa, acesse o artigo original em: https://revistatopicos.com.br/artigos/phytochemical-profile-phenolic-and-flavonoid-content-and-antifungal-activity-of-the-resinous-extract-of-protium-spruceanum-benth-engler?noblockage

Note: Values initially expressed in millimeters (mm) and converted into mycelial growth inhibition percentages (%). Frowncide Fungicide 500 SC® (100%) was used as the positive control, whereas DMSO (0%) was used as the negative control. Means followed by the same letter within the same row do not differ significantly according to *Tukey's* test at the 5% probability level ($p \leq 0.05$). Source: Authors (2026). Authors, 2026.

4. DISCUSSION

The qualitative phytochemical screening of the hydroethanolic resin extract of *P. spruceanum* revealed a diverse chemical profile characterized by the presence of phenolic compounds, flavonoids, alkaloids, saponins, resins, tannins, steroids, organic acids, non-reducing sugars, catechins, and amino acids (Table 1).

This rich secondary metabolite composition is consistent with the biochemical signature of the Burseraceae family, whose species are widely recognized for synthesizing complex resinous matrices rich in bioactive constituents utilized in plant defense mechanisms against environmental stressors and phytopathogens (Amparo *et al.*, 2019; Bruzinga *et al.*, 2022). Similar phytochemical screening profiles have been documented for other resin-producing and medicinal botanical extracts, reinforcing that secondary metabolites such as flavonoids, tannins, and saponins frequently operate synergistically to confer broad protective functions (Ferreira *et al.*, 2023; Madisha, 2024).

The quantitative phytochemical analysis revealed substantial levels of total phenolic compounds and flavonoids in the *P. spruceanum* resin extract. These findings are consistent with previous

investigations of hydroethanolic extracts from medicinal and aromatic plants, in which phenolic compounds generally predominate as major bioactive constituents (Aiyegroro; Okoh, 2010; Yadav; Agarwala, 2011).

Compared with other resin extracts and oleoresins from the genus *Protium*, such as *P. heptaphyllum* and *P. amazonicum*, which are predominantly characterized by volatile mono- and sesquiterpenes, hydroethanolic extraction allows for the recovery of a diverse range of polar and semipolar phenolic compounds and flavonoids. This substantial phytochemical content highlights the considerable biotechnological potential of *P. spruceanum* resin extracts, as these metabolites are associated with important antioxidant and antimicrobial properties (Amparo *et al.*, 2019; Sousa *et al.*, 2025).

In the *in vitro* antifungal assays, *P. spruceanum* resin extract exhibited relevant concentration-dependent inhibitory effects against all phytopathogenic fungal strains evaluated (*A. flavus*, *A. niger*, *C. gloeosporioides*, *C. acutatum*, and *S. sclerotiorum*) (Table 2). The 100% extract concentration resulted in the highest rates of mycelial growth inhibition, reaching 30.39% against *C. gloeosporioides* and 24.03% against *S. sclerotiorum*.

These findings are consistent with recent studies investigating botanical and resin extracts against agricultural phytopathogens, which similarly report that higher concentrations of crude plant extracts significantly compromise fungal cell integrity and suppress mycelial development (Haab *et al.*, 2026; Satyal *et al.*, 2017). Although essential oils derived from *Protium* resins often exhibit selective or moderate antimicrobial activity, largely associated with their volatile terpene fractions (de Lima *et al.*, 2016; Satyal *et al.*, 2017), the broader

spectrum of activity observed in polar resin extracts may be largely attributed to the combined presence of phenolic compounds, tannins, and flavonoids (Table 1).

It is worth emphasizing that, although *P. spruceanum* resin extract exhibited notable antifungal activity, its inhibition rates remained substantially lower than those achieved by the commercial synthetic fungicide, which provided 100% inhibition against all five fungal strains evaluated. This finding provides a more balanced perspective on the potential of the resin extract as a botanical antifungal agent, highlighting its potential application in green chemistry strategies and as a complementary alternative to conventional synthetic chemical fungicides. Further investigations are needed to evaluate its efficacy, possible synergistic interactions with commercial fungicides, and potential applications in sustainable plant disease management.

Mechanistically, the antifungal efficacy of plant extracts rich in phenolics and flavonoids is primarily ascribed to the affinity of hydroxyl groups toward fungal cell wall proteins, leading to enzymatic inhibition, membrane perturbation, and transmembrane leakage of vital intracellular electrolytes and constituents (Aiyegroro; Okoh, 2010; Madisha, 2024).

Although the commercial chemical fungicide Frowncide 500 SC® achieved superior inhibition compared to the plant extract—as expected for synthetic standard controls—the moderate-to-high inhibition rates demonstrated by the crude resin extract, particularly against *C. gloeosporioides*, underscore the viability of *P. spruceanum* as a promising natural alternative or complementary agent for

integrated pest management programs in tropical agricultural systems (Amparo *et al.*, 2019; Haab *et al.*, 2026).

5. CONCLUSION

The hydroethanolic extract of *Protium spruceanum* resin exhibits a diverse phytochemical profile, characterized by the presence of important classes of secondary metabolites, particularly phenolic compounds, flavonoids, tannins, and saponins, as well as substantial total phenolic and flavonoid contents. The oleoresin demonstrates *in vitro* antifungal potential against phytopathogenic fungi of significant agricultural importance *Aspergillus flavus*, *Aspergillus niger*, *Colletotrichum gloeosporioides*, *Colletotrichum acutatum*, and *Sclerotinia sclerotiorum*), inhibiting mycelial growth in a concentration-dependent manner.

Although its efficacy was lower than that observed for the standard synthetic fungicide, the results indicate that the resin extract possesses moderate to relevant bioactivity, particularly against *C. gloeosporioides* and *S. sclerotiorum*. Thus, this species represents a promising source of natural bioactive metabolites, opening new perspectives for the development of complementary and sustainable strategies aimed at the integrated management of plant diseases and the preservation of agricultural products.

REFERENCES

Abdel Gwad MM, El-Sayed ASA, Abdel-Fattah GM, Abdelmoteleb M, Abdel-Fattah GG. Potential fungicidal and antiaflatoxigenic effects of cinnamon essential oils on *Aspergillus flavus* inhabiting the stored wheat grains. BMC Plant Biology, 2024;24,394. DOI:

https://doi.org/10.1186/s12870-024-05065-w. Accessed at: November 16, 2026.

Aiyegroro OA, Okoh AI. Preliminary phytochemical screening and in vitro antioxidant activities of aqueous extract of *Helichrysum longifolium* DC. BMC Complementary and Alternative Medicine, 2010;10(1). DOI: https://doi.org/10.1186/1472-6882-10-21. Assecced at: September 16, 2026.

Amparo TR, Rodrigues IV, Seibert JB, Almeida TC, Cabral VAR, Vieira PMA, Brandão GC, Oliveira MLG, Silva GN, Santos ODH, Vieira Filho AS, Teixeira LFM, Souza GHB. Antibacterial substances from leaves of *Protium spruceanum* (Burseraceae): *in vitro* and *in silico* evaluation. Brazilian Journal of Pharmaceutical Sciences, 2020;56,e18474. DOI: http://doi.org/10.1590/s2175-97902020000118474. Accessed at: November 17, 2026.

Amparo TR, Seibert JB, Mathias FAZ, Vieira JFP, Aguar Soares RDO, Freitas KM, Cabral VAR, Brandão GC, Santos ODH, Souza GHB, Vieira PMA. Anti-inflammatory activity of *Protium spruceanum* (Benth.) Engler is associated to immunomodulation and enzymes inhibition. Journal of Ethnopharmacology, 2019;241,112024. DOI: https://doi.org/10.1016/j.jep.2019.112024. Assecced at: September 11, 2026.

Amparo TR, Silva ACP, Seibert JB, Silva DS, Santos VMR, Vieira, PMA, Brandão GC, Souza GHB, Santos BAMC. *In vitro* and in silico investigation of the photoprotective and antioxidant potential of *Protium spruceanum* leaves and its main flavonoids. Journal of Photochemistry and Photobiology A: Chemistry, 2022;431,114037.

DOI: https://doi.org/10.1016/j.jphotochem.2022.114037. Accessed at: November 18, 2026.

Ashokkumar S, Dahal R, Shin YO, Uhm HS, Park JS, Lee Y-C, Choi EH. Deactivation of *Colletotrichum acutatum* and *Colletotrichum gloeosporioides* by novel cylindrical dielectric barrier discharge plasma: Maintaining biochemical composition in strawberry by *in-vitro* and *in-vivo*. Food Control, 2026;181,111722. DOI: https://doi.org/10.1016/j.foodcont.2025.111722. Accessed at: November 17, 2026.

Bandeira CFP, Velasques J, Santos GB, Cardoso CAL, Rocha VR, Ferreira MM, Pinto AB, Costa EA, Coutinho JP, Oliveira HVV, Santos TA, Pirovani CP. *Protium heptaphyllum*, a tree native to the Atlantic forest, its a potential source of compounds against important cocoa phytopathogen. Scientific Reports, 2026;16, 18811. DOI: https://doi.org/10.1038/s41598-026-49462-7. Accessed at: November 17, 2026.

Bruzinga WSJS, Ribeiro LM, Nunes YRF, Pimenta LPS, Almeida MAT, Mendes MGA, Mercadante-Simões MO. Ontogenesis of resin ducts and secretory process in *Protium spruceanum* (Burseraceae) stems. Microscopy and Microanalysis, 2022;28(3),744-755. DOI: https://doi.org/10.1017/S1431927622000459. Accessed at: August 22, 2026.

Carvajal D, Alvarez R, Osorio E. Chemical variability of essential oils of *Protium colombianum* from two tropical life zones and their *in vitro* activity against isolates of *Fusarium*. Journal of Pest Science, 2025;89,241-248. DOI: https://doi.org/10.1007/s10340-015-0667-x. Accessed at: November 18, 2026.

de Lima EM, Cazelli DSP, Pinto FE, Mazuco RA, Kalil IC, Lenz D, Scherer R, Andrade TU, Endringer DC. Essential oil from the resin of *Protium heptaphyllum*: Chemical composition, cytotoxicity, antimicrobial activity, and antimutagenicity. Pharmacognosy Magazine, 2016;12(1),S42-S46. DOI: https://doi.org/10.4103/0973-1296.176113. Accessed at: September 15, 2026.

de Lima MCF, Ribeiro R, Almeida e Silva JE, Tavares SSS, Araújo YCD, Veiga-Júnior VF. Chemistry, biological activities, and uses of Copaiba oil resins. Gums, Resins and Latexes of Plant Origin, 2022;377-397. DOI: https://doi.org/10.1007/978-3-030-91378-6_19. Accessed at: November 18, 2026.

Dias ALB, Sousa WC, Batista HRF, Alves CCF, Souchie EL, Silva FG, Pereira OS, Sperandio EM, Cazal CM, Forim MR, Miranda MLD. (2020). Chemical composition and in vitro inhibitory effects of essential oils from fruit peel of three *Citrus* species and limonene on mycelial growth of *Sclerotinia sclerotiorum*. Brazilian Journal of Biology, 2020;80(2),460-464. DOI: https://doi.org/10.1590/1519-6984.216848. Accessed at: November 18, 2026.

Duan, W-Y, Zhu X-M, Zhang S-B, Lv Y-Y, Zhai H-C, Wei S, Ma P-A, Hu Y-S. Antifungal effects of carvacrol, the main volatile compound in *Origanum vulgare* L. essential oil, against *Aspergillus flavus* in postharvest wheat. International Journal of Food Microbiology, 2024;410,110514. DOI: https://doi.org/10.1016/j.ijfoodmicro.2023.110514. Accessed at: November 12, 2026.

Ferreira WU, Menezes Filho ACP, Sharma P, Castro CFS, Ferreira LU, Ventura MVA. Phytochemical prospecting and biological activities of the floral extract from [*Impatiens walleriana* (Hook.)]

(Balsaminaceae). Brazilian Journal of Science, 2023;2(11),43-50. DOI: https://doi.org/10.14295/bjs.v2i11.398. Assecced at: October 10, 2026.

Fontana DC, .Schmidt D, Kulcszynski SM, Caron BO, Pretto MM, Mariotto AB, Santos J, Holz E. Fungicidal potential of essential oils in control of *Fusarium* spp. and *Sclerotinia sclerotiorum*. Arquivos do Instituto Biológico, 2020;87,1-10. DOI: https://doi.org/10.1590/1808-1657000612019. Accessed at: November 18, 2026.

Gong A, Song M, Zhang J. Current strategies in controlling *Aspergillus flavus* and aflatoxins in grains during storage: A review. Sustainability, 2024;16(8),3171. DOI: https://doi.org/10.3390/su16083171. Accessed at: November 17, 2026.

Haab A, Miglioretto LM, Schauren D. Avaliação da atividade antifúngica de diferentes extratos vegetais no controle de *Aspergillus niger*, agente causador do mofo preto da cebola. Revista Tópicos, 2026;4(36),1-14. DOI: https://doi.org/10.70773/revistatopicos/785908147. Assecced at: September 08, 2026.

Hossain MM, Sultana F, Li W, Tran L-SP, Mostofa MG. *Sclerotinia sclerotiorum* (Lib.) de Bary: Insights into the pathogenic features of a global pathogen. Cells, 2023;12(7),1063. DOI: https://doi.org/10.3390/cells12071063. Accessed at: November 18, 2026.

Law CW, Hashim N, Ismail SI, Jahari M, Al Riza DF. A review on anthracnose disease caused by *Colletootrichum* spp. in fruits and advances in control strategies. International Journal of Food Microbiology, 2025;442,111397. DOI: https://doi.org/10.1016/j.ijfoodmicro.2025.111397. Accessed at: November 18, 2026.

Lima RF, Aparecido LEO, Torsoni GB, Rolim GS. Climate change assessment in Brazil: Utilizing the Köppen-Geiger (1936) climate classification. Revista Brasileira de Meteorologia, 2023;38,e38230001. DOI: http://doi.org/10.1590/0102-77863810001. Assecced at: September 06, 2026.

Madisha JK. Preliminary phytochemical analysis and antibacterial activity of *Malva parviflora* against respiratory and dermatological pathogens. Research Square, 2024. DOI: https://doi.org/10.21203/rs.3.rs-4688628/v1. Assecced at: October 10, 2026.

Menezes Filho ACP Santos MC, Castro CFS. Avaliação fitoquímica, físico-química e atividades antioxidante, hemotóxica e antibacteriana do extrato de *Protium spruceanum* (Benth.) Engl. Journal of Biotechnology and Biodiversity, 2021;9(1),48-59. DOI: https://doi.org/10.20873/jbb.uft.cemaf.v9n1.menezesfilho. Accessed at: November 18, 2026.

Menezes Filho ACP, Cristofoli M, Ventura MVA, Taques AS, Alves I, Castro CFS. Essential oil from petioles of *Protium ovatum* Engl. (Burseraceae) has bioactive and antifungal activity? Brazilian Journal of Science, 2022;1(7),26-36. DOI: https://doi.org/10.14295/bjs.v1i7.151. Accessed at: November 18, 2026.

Morkeliūnė A, Rasiukevičiūtė N, Šernaitė L, Valiuškaitė A. The use of essential oils from thyme, sage and peppermint against *Colletotrichum acutatum*. Plants, 2021;10(1),114. DOI: https://doi.org/10.3390/plants10010114. Accessed at: November 11, 2026.

Peralta-Ruiz, Y, Rossi C, Grande-Tovar CD, Chaves-López C. Green management of postharvest anthracnose caused by *Colletotrichum gloeosporioides*. Journal of Fungi, 2023;9(6),623. DOI: https://doi.org/10.3390/jof9060623. Accessed at: November 18, 2026.

Rodrigues GC, Marcionilio SMLO, Martins CHG, Pedroso RS, Santiago MB, Oliveira TAS, Costa MPP, Crotti AEM, Miranda MLD. Bioprospecting the *Cerrado's* aromatic flora: Chemical and biological studies of three essential oils. Brazilian Archives of Biology and Technology, 2023;66,e23220034. DOI: https://doi.org/10.1590/1678-4324-2023220034. Accessed at: November 18, 2026.

Satyal P, Powers CN, Parducci RV, McFeeters RL, Setzer WN. Chemical composition, enantiomeric distribution, and antifungal activity of the oleoresin essential oil of *Protium amazonicum* from Ecuador. Medicines, 2017;4(4),70. DOI: https://doi.org/10.3390/medicines4040070. Accessed at: September 20, 2026.

Shang Q, Jiang D, Xie J, Cheng J, Xiao X. The schizotrophic lifestyle of *Sclerotinia sclerotiorum*. Molecular Plant Pathology, 2024;25(2),e13423. DOI: https://doi.org/10.1111/mpp.13423. Accessed at: November 11, 2026.

Sharma AD, Kaur I, Chauhan A. Molecular docking studies of principal components and in vitro inhibitory activities of Rosmarinus officinalis essential oil against *Aspergillus flavus*, *Aspergillus fumigatus* and *Mucor indicus*. Phytomedicine Plus, 2023;3(4),100493. https://doi.org/10.1016/j.phyplu.2023.100493. Accessed at: November 16, 2026.

Silva DC, Sakuragui CM. (2024). Flora of Rio de Janeiro: *Protium* Burm. f. (Burseraceae). Rodriguésia, 2024;75,e00012023. DOI: https://doi.org/10.1590/2175-7860202475018. Accessed at: November 17, 2026.

Sousa WC, Oliveira Filho JG, Pereira AK, Silva SS, Kassab G, Christofoli M, Alves CCF, Matos AP, Forim MR, Cazal CM. Composition, antioxidant capacity and antimicrobial activity of volatile organic compounds of *Protium ovatum* Eng. from different regions in Brazilian Savannah. Química Nova, 2025;48(2),e20250020. DOI: http://doi.org/10.21577/0100-4042.20250020. Accessed at: September 12, 2026.

Veloso PHF, Lacerda GA. (2025). Avaliação da capacidade antioxidante, quantificação de fenólicos e perfil UV do extrato acetato de etila de *Protium spruceanum* Benth. Engl. Revista Fitos, 2025;19. DOI: https://doi.org/10.32712/2446-4775.2025.1825. Accessed at: November 17, 2026.

Yadav RNS, Agarwala M. Phytochemical analysis of some medicinal plants. Journal of Phytology, 2011;3(12),10-14. Assecced at: October 11, 2026.

Yuan, T Hua Y, Zhang D, Yang C, Lai Y, Li M, Ding S, Li S, Chen Y. Efficacy and antifungal mechanism of Rosemary essential oil against *Colletotrichum gloeosporioides*. Forests, 2024;15(2),377. DOI: https://doi.org/10.3390/f15020377. Accessed at: November 17, 2026.

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