Scientific Electronic Archives
Issue ID: Sci. Elec. Arch. Vol. 16 (8)
August 2023
DOI: http://dx.doi.org/10.36560/16820231769
Article link: https://sea.ufr.edu.br/SEA/article/view/1769

ISSN 2316-9281

Natural products: the contribution of research developed by a university in Sinop, Brazil

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Abstract. Bioactive compounds present in plants, microorganisms, and animals are the subject of scientific research, mainly focusing on the discovery of novel pharmacologically active molecules for application in human and veterinary medicine, as well as agriculture. Brazil is the country with the greatest biodiversity globally, accounting for 15–20% of global diversity. Therefore, the objective of the present study was to carry out a bibliographic survey on studies involving natural compounds conducted by staff of the Federal University of Mato Grosso, Sinop campus. The review included scientific articles published in specialized journals by the staff from the moment they were hired, according to information in their Lattes Curriculum. During the survey period, the campus had 314 staff, and 311 scientific articles were published. Among the 311 articles, 122 studies met the inclusion criteria and were selected for this literature review. According to the findings, UFMT – Sinop has contributed to research in the field of natural products, carrying out studies on the biological effects of compounds present in extracts obtained from plants, microorganisms, and animal secretions.
Keywords: natural products, biological effect, bioprospecting.

Introduction

Natural products represent a comprehensive set of chemical compounds with diverse biological effects and broad applications in human and veterinary medicine, in addition to agriculture (KATZ; BALTZ, 2016). They are obtained from plants, microorganisms, marine organisms, insects, and other animals, being a source of biologically active substances, mainly secondary metabolism products (BARREIRO; BOLZANI, 2009; KATZ; BALTZ, 2016). Secondary metabolites are molecules that are not essential for the survival of living beings under experimental conditions, although they facilitate survival in the wild (KATZ; BALTZ, 2016). For example, such compounds are essential for adaptation to habitats, physical environmental factors, and climatic factors, in addition to offering protection against predators and pathogens (VALLI; RUSSO; BOLZANI, 2018). Furthermore, numerous secondary metabolites are invaluable raw materials for the production of several contemporary drugs (BARREIRO; BOLZANI, 2009).

Most drugs in clinical use today originate from natural products or were developed by chemical synthesis (BARREIRO; BOLZANI, 2009). As of 2013, approximately 1,453 new chemical structures had been approved by the US Food and Drug Administration, with 40% based on semi-synthetic or synthetic products or originating from natural compounds (KATZ; BALTZ, 2016). In the 1981–2014 period, about 60% of all pharmaceutical products launched on the world market were derived from or mimicked molecules obtained from natural products (VALLI; RUSSO; BOLZANI, 2018). Some examples of important natural products in the pharmaceutical industry are morphine, isolated from Papaver somniferum (BARREIRO; BOLZANI, 2009); bradykinin, isolated from the venom of Bothrops jararaca (VALLI; RUSSO; BOLZANI, 2018); azidothymidine (AZT), isolated from nucleosides from seaweed (BARREIRO; BOLZANI, 2009); in addition to a broad range of antibiotics, such as penicillin (KATZ; BALTZ, 2016), obtained from bacteria and fungi (BARREIRO; BOLZANI, 2009); and antiparasitic drugs, such as artemisinin (ZHANG, 2019).

Such discoveries highlight the importance of biodiversity studies. Biodiversity can be defined as the variety and complexity of living organisms, covering all species, including their interaction with ecological systems (VALLI; RUSSO; BOLZANI, 2018).

Brazil is the country with the greatest biodiversity in the world, covering six terrestrial biomes (Amazon Forest, Caatinga, Cerrado, Atlantic Forest, Pantanal, and Pampa), three large marine ecosystems (North, East, and South), and 12 hydrographic regions (VALLI; RUSSO; BOLZANI, 2018). According to the Convention on Biological Diversity, Brazil hosts between 15–20% of all the global diversity, which represents approximately 55,000 species of plants, 517 amphibians, 1,622 birds, 524 mammals, 468 reptiles, 3,000 species of freshwater fish, and approximately 15 million insects, many still completely unknown (BARREIRO; BOLZANI, 2009).

Considering the biological wealth above, research in the area of bioprospecting has been increasing with the objective of identifying and isolating value-added bioproducts (BARREIRO; BOLZANI, 2009). Examples of such initiatives include the BIOTA-FAPESP Program and the National Policy on Medicinal Plants and Herbal Medicines (BARREIRO; BOLZANI, 2009; ZUANAZZI; MAYORGA, 2010). Such programs encourage the cataloging of species in the Brazilian ecosystem, research on biologically active substances that can be prototypes of drugs or plant-based drugs, in addition to improving the quality of life of populations through safe, rational, and sustainable access to natural products as therapeutic alternatives in a holistic health system (BARREIRO; BOLZANI, 2009; ZUANAZZI; MAYORGA, 2010).

Another important aspect is the production chain associated with the study of biodiversity, called bioeconomy. Bioeconomy involves all economic activities derived from bioproducts and processes that contribute to sustainable and efficient production of food, chemicals, materials, and energy, and the protection of the environment ecosystem health (VALLI; RUSSO; BOLZANI, 2018). Therefore, the study of biodiversity boosts national technological development based on multidisciplinary basic and applied research associated with agricultural and industrial production technology, allowing the profitable use of such knowledge on a large scale for the production of medicine, cosmetics, food supplements, agricultural pesticides, and other products (BARREIRO; BOLZANI, 2009; VALLI; RUSSO; BOLZANI, 2018); ZUANAZZI; MAYORGA, 2010).

Therefore, the objective of the present study was to conduct a bibliographic survey of research on the evaluation of the biological effect of natural products conducted by staff at the Federal University of Mato Grosso (Universidade Federal do Mato Grosso – UFMT), Sinop campus, considering the importance of disseminating knowledge in the field for the development of bioeconomy, as well as for the enhancement of bioprospecting research.

Methods

Bibliographic survey

The bibliographic survey included the collection of articles published by staff at the UFMT - Sinop campus, available on the Lattes Platform of the National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq). The full articles were obtained from the search engines for indexed journals, including SciELO, PubMed, and the CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Coordination for the Improvement of Higher Education Personnel) Periodical Portal. In addition, the afore mentioned websites were searched for articles using the researcher’s name in case the Lattes Curriculum was out of date.

Inclusion criteria

The inclusion criteria were studies involving the evaluation of the biological effects of isolated compounds, fractions or crude extracts obtained from plants, microorganisms, or animal secretions; published in specialized scientific journals from the date the member of staff was admitted into the UFMT - Sinop.

Exclusion criteria

Scientific publications that did not involve the study of natural products, or that had been published before the admission of the researcher at UFMT – Sinop Campus, or works disseminated through means other than specialized scientific journals, were not considered.

Results and discussion

In the period from November 7–13, 2019, the UFMT – Sinop Institutes had 314 staff, out of which 271 were professors and 43 were administrative technicians. Among them, 54.8% were affiliated with the Institute of Health Sciences (Instituto de Ciências da Saúde - ICS), 20.4% were affiliated with the Institute of Natural, Human, and Social Sciences Instituto de Ciências Naturais, Humanas e Sociais - ICNHS), and 24.8% were affiliated with the Institute of Agricultural and Environmental Sciences (Instituto de Ciências Agrárias e Ambientais - ICAA).

Most of the staff joined UFMT – Sinop in 2009–2014 (51.9%), and 29.9% joined in 2015–2020. The campus was instituted in 2006, offering regular undergraduate courses and hiring the first staff (2006–2008: 17.2%).

Initially, UFMT – Sinop was a pedagogical center offering modular special classes in the fields of Biology, Law, Forest Engineering, and Accounting Sciences. Currently, the campus is composed of three Institutes (ICS, ICNHS, and ICAA); offers 10 undergraduate courses (Agronomy, Nursing, Forestry Engineering, Medicine, Veterinary Medicine, Animal Husbandry, Agricultural and Environmental Engineering, Natural Sciences with qualifications in Physics, Chemistry, and Mathematics); offers three strictu sensu postgraduate programs (Environmental Sciences, Animal Husbandry, and Health Sciences); offers one professional master's degree program (Natural Sciences and Mathematics Teaching); and one latu sensu postgraduate Program (Grain and Seed Production, Processing, and Post-harvesting).

The curriculum vitae available at Plataforma Lattes - CNPq and the indexed journals in the search engines were analyzed from April 3, 2020 to March 26, 2021. The analysis of the collected data showed that 47.3% of the UFMT - Sinop servants graduated in the broad field of health sciences, followed by the fields of agricultural (24.8%) and natural sciences (24.5%). The data corroborate the number of staff in each institute, since the ICS has the largest number of staff in the campus. The broad field of languages also featured, with 0.3% of the staff graduating with associated qualifications, whereas 3.4% did not fall under the graduating faculty in the Lattes Platform – CNPq.

Regarding degree qualification, most of the faculty had a doctorate (graduate: 2.51%; postgraduate: 16.3%; master's degree: 17.24%; doctorate degree: 59.87%; no response: 4.08 %), with only 25.1% reporting working in Postgraduate Programs (yes, 25.1%; no, 68.7%; no response, 6.3%), despite the campus having five ongoing postgraduate programs.

The objective of the present study was to evaluate the scientific output of campus staff on the biological effects of natural products. According to the inclusion and exclusion criteria, 311 studies were selected, out of which 292 were conducted by professors and 16 by technicians. Out of the total, 23.8% (74) were developed in collaboration among campus staff (between professors and between professors and technicians); therefore, they were omitted due to duplicity.

Out of the 237 articles selected, 228 full articles were obtained. They were read from March 22, 2021 to July 14, 2022. After reading and studying the articles, 28 were excluded for being duplication and 78 were excluded for being outside the scope of the study, with 122 being included in the present review.

Diversity of studies on natural products conducted at UFMT – Sinop

UFMT was established in 1970 and is located in all regions of the state of Mato Grosso, with campuses in the state capital, Cuiabá (headquarters), Várzea Grande, Barra do Garças, Pontal do Araguaia (Campus Araguaia), Sinop, and Lucas do Rio Verde (under implementation) (UNIVERSIDADE FEDERAL DE MATO GROSSO, 2022). In addition, it has an Advanced Research Base in the Pantanal and two experimental farms, one in Santo Antônio do Leverger and the other in Sinop (UNIVERSIDADE FEDERAL DE MATO GROSSO, 2022).

The state of Mato Grosso is located in the central-west region of Brazil and has an estimated population of 3,567,234 inhabitants (2021) (MODESTO et al., 2022). The state comprises areas of the Cerrado, Pantanal, and Amazon biomes (FERREIRA; TERÇAS-TRETTEL, 2022). Sinop is one of the 141 municipalities in the state and has an estimated population (2021) of 148,960 inhabitants (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2022 a,b). The city is located in the area known as the Legal Amazon, a region delimited with the purpose of promoting inclusive and sustainable development to competitively integrate the regional production base into the national and international economy (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2022 c). Therefore, it UFMT is located in an area with high biodiversity, representing an extensive area of scientific research within the scope of natural products (UNIVERSIDADE FEDERAL DE MATO GROSSO, 2022).

Natural products and derivatives are characterized by high chemical and structural diversity, varied biological activity, and low toxicity and side effects (DENG et al., 2019). Furthermore, they can be obtained from a wide variety of sources (DENG et al., 2019). Currently, there is great interest in the study of such products, since isolated bioactive compounds can be used in several areas, such as in the pharmaceutical and nutraceutical industry (CHOPRA; DHINGRA, 2021; DENG et al., 2019). Many natural compounds are already known for their biological activities, including polyphenols (e.g., curcumin, resveratrol), cardiotonic steroids (e.g., digoxin and bufalin), terpenoids (e.g., paclitaxel, artemisinin, and triptolide), polysaccharides (e.g., lentinan), saponins, and capsaicin (CHOPRA; DHINGRA, 2021; DENG et al., 2019).

In this context, the UFMT – Sinop has contributed to research in the area of natural products, developing studies on the biological effect of compounds present in extracts obtained from plants, microorganisms, and animal secretions.

Studies on the biological effect of plant extracts

Most studies were on plant compounds, with 85 articles selected. The articles evaluated the antimicrobial, antioxidant, anti-inflammatory, immunomodulatory, mutagenic, cytotoxic, antitumor, healing, antidiabetic, anti-nociceptive, analgesic, and antidiarrheal activities of the compounds studied. In addition, some analyzed the application of natural plant products in animal production and agriculture, e.g., as phytoalexin elicitors. Two studies involved ethnobotanical studies and literature reviews.

The antimicrobial activities of natural compounds were evaluated mainly against parasitic and fungal disease-causing agents in cultivated plants. The repellent and insecticidal action of natural compounds were evaluated in agriculture. The antimicrobial effects against human pathogens were evaluated, as in onychomycosis and trichomoniasis.

Almeida et al. (2016) and Fonseca et al. (2017) demonstrated that extracts obtained from Azadirachta indica (neem), Manihot esculenta (cassava), and Anadenanthera macrocarpa (black angico) inhibit the development of Meloidogyne incognita (nematodes) in cotton and tomato crops. Root-knot nematodes of the genus Meloidogyne are considered the most important plant parasitic nematodes globally, exhibiting broad host ranges and causing economic losses in several crops (ALMEIDA et al., 2016).

Another pest that affects agriculture is mites (LUCINE et al., 2010). The Tetranychidae family comprises species of phytophagous mites, such as the two-spotted spider mite (Tetranychus urticae Koch, 1836) and the red spider mites (Tetranychus desertorum Banks, 1900, and Tetranychus ludeni Zacher, 1913), which damage the major cultivated species (LUCINE et al., 2010). Capsicum baccatum (bishop’s hat pepper) extracts can reduce T. ludeni egg laying and seem to have a repellent action against mites, demonstrating pest management potential (LUCINE et al., 2010).

The fungicidal action of compounds obtained from plants has also been studied in agriculture. Bulhões et al. (2012) evaluated the effect of crude extracts of Corymbia citriodora (lemon-scented gum), Azadirachta indica (neen), and Cymbopogon nardus (citronella grass) in controlling infections caused by Colletotrichum gloeosporioides (anthracnose) and Cladosporium herbarum (cladosporiosis), as well as in disease caused by bacterial infection with Xanthomonas axonopodis pv. passiflorae (bacteriosis) in passion fruit trees. The extracts were not effective in controlling anthracnose and cladosporiosis; however, neen and citronella grass extracts exhibited bacteriosis control potential (BULHÕES et al., 2012). However, the control of anthracnose caused by C. musae in banana crops and by C. gloeosporioides in bell pepper by Caryocar brasiliense (pequi) and Cymbopogon citratus (lemongrass) extracts, respectively, was not efficient (CARVALHO et al., 2008; MENDES et al., 2013).

The in vitro fungicidal activity of raw extracts of Ruta graveolens L (rue), Origanum majorana (marjoram), Baccharis trimera (baccharis), Hyemenolobium petraeum (angelim), and Corymbia citriodora (lemon-scented gum) against anthracnose on cotton leaves was not promising (SANTOS; BONALDO; BULHÕES, 2011). However, rue, marjoram, baccharis, and angelim extracts controlled ramulose, a fungal disease caused by Colletotrichum gossypii var. cephalosporioides, in cotton (SANTOS; BONALDO; BULHÕES, 2011). Ramulose resistance in cotton was observed following treatment with Rosmarinus officinalis (rosemary), Baccharis trimera (baccharis), Cymbopogon citratus (lemongrass), Ocimum basilicum (basil), and Corymbia citriodora (lemon-scented gum) essential oils (SANTOS; BULHÕES; BONALDO, 2016).

Essential oils are complex substances that comprise mixtures of more than 100 types of chemical compounds (RAMSEY et al., 2020). Although their chemical compositions vary depending on type of soil, origin, climatic conditions, and production method, terpenes are the main chemical class found in essential oils (RAMSEY et al., 2020). Antibacterial, antifungal, and antiviral activity has already been widely described for such substances (RAMSEY et al., 2020). UFMT – Sinop researchers evaluated the antifungal activity of essential oils in conserving foods such as Brazil nut (LORINI; BONALDO; MENDES, 2016) and tomato (MACHADO et. al., 2017), in developing in vitro Corynespora cassiicola, a fungus that forms necrotic leaf spots in cucumber, papaya, acerola, soybean, among others (CARLOS et al., 2010), and in treating onychomycosis (LIMA; RIBEIRO; BONALDO, 2014). Cinnamomum cassia (cinnamon), Syzygium aromaticum (carnation), and Corymbia citriodora (lemon-scented gum) essential oils exhibited inhibitory activity against Penicillium sp. (lemon-scented gum), Rhizopus sp. (carnation), Aspergillus niger, and Aspergillus flavus, growth with cinnamon being efficient in inhibiting all the fungi studied (LORINI; BONALDO; MENDES, 2016). Copaifera sp. (copaiba) and Rosmarinus officinalis (rosemary) oils increased tomato shelf life by potentially reducing fruit respiration rate (MACHADO et al., 2017). In addition, copaiba oil had promising effects in combating the main phytopathogenic fungi in post-harvest tomato, presenting results to similar to those of the commercial fungicide used as a control (MACHADO et al., 2017).

Carlos et al. (2010) reported that the essential oil of Achillea millefolium (yarrow) could inhibit the in vitro sporulation of C. cassiicola, being able to control the disease in cucumber. In addition, Lima et al. (2014) demonstrated the antifungal activity of Syzygium aromaticum (clove) essential oil against Aspergillus niger and Aspergillus flavus, which causes onychomycosis.

The use of natural products to manage agricultural pests is a promising alternative to conventional agrochemical treatments (BULHÕES et al., 2012; CARVALHO et al., 2008). Agricultural pesticides pose environmental risks, contaminating rivers, soil, fauna and flora, with potential adverse effects on human health (BULHÕES et al., 2012; CARVALHO et al., 2008). In addition, agricultural pesticides are expensive and many phytopathogens are developing resistance to agrochemicals (BULHÕES et al., 2012; CARVALHO et al., 2008).

In addition to direct antimicrobial effects, natural products appear to be phytoalexin elicitors.

Phytoalexins are low-molecular weight antimicrobial secondary metabolites produced by plants in response to physical, chemical, or biological stress that can reduce or prevent phytopathogen activity (MOREIRA et al., 2008). Phytoalexins appear to impart plant resistance to infection by accumulating in tissues and inducing resistance gene expression (MATIELLO; BONALDO, 2013). An example of a phytoalexin is the glycolin (pterocarpanoid) produced by soybean, which is important for resistance against phytopathogens in legumes (MATIELLO et al., 2016).

Colpas et al. (2008) observed that extracts from Ocimum gratissimum L. leaves act as phytoalexin elicitors in soybean and sorghum, increasing glyceollin and deoxyanthocyanidin production, respectively. The extracts also induce anthracnose resistance (C. lagenarium) in cucumber (COLPAS et al., 2008). Similar effects were observed by Moreira et al. (2009) with partially purified fractions of citronella alcoholic extracts (C. nardus). Raw extracts and tinctures of rue (R. graveolens), baccharis (B. trimera), marjoram (O. majorana), angelim (H. petraeum), cambará (Q. albiflora) and lemon-scented gum (C. citriodora) also act as phytoalexin elicitors in soybean (MATIELLO; BONALDO, 2013; MATIELLO et al., 2016). However, elicitor activity in sorghum was only observed with extracts from the plants (MATIELLO; BONALDO, 2013; MATIELLO et al., 2016).

Another study conducted by UFMT – Sinop researchers evaluated the antiparasitic action of Mentha crispa (Giamebil®) (MORAES et al., 2012). This commercial formulation is commonly used for the treatment of infections caused by Entamoeba histolytica and Giardia lamblia; however, it showed promising results in the treatment of Trichomonas vaginalis infections, exhibiting efficiency similar to that of conventional treatment with secnidazole, but with less adverse effects (MORAES et al., 2012).

The cytotoxic effects of plant extracts were also evaluated. The research community recommends that products with unknow action have their biocompatibility evaluated initially through in vitro cell culture studies (CASTOLDI et al., 2020 a). In vitro cytotoxicity tests involve the observation of cellular changes following direct or indirect contact with compounds or substances, with the analysis of cell viability being one of the main parameters used (CASTOLDI et al., 2020 a). Following in vitro studies, the material or compound may subsequently enter animal studies and human clinical trials (CASTOLDI et al., 2020 a).

Studies by our research group have demonstrated that the Específico Pessoa herbal tincture® is cytotoxic to Ehrlich tumor cells (murine mammary adenocarcinoma) and normal murine splenocytes, especially at high doses (CASTOLDI et al., 2020 a). The effect seems to be a consequence of Brazilian harpalyce Benth (snake root) pterocarpans present in the tincture (CASTOLDI et al., 2020 a). A similar result has been observed with methanolic extract and acetogenin-rich extract obtained from Duguetia sp. (Annonaceae) (CASTOLDI et al., 2020 b). Our research group also evaluated the activity of Callisthene fasciculata (Spr.) Mart. (carvoeiro) leaf extract on mouse splenic and Ehrlich tumor cells, and observed that the extract has cytotoxic action at low concentrations; however, at high concentrations, it has opposite effects (CASTOLDI et al., 2018). The activity reflects the complexity of unpurified extracts, a consequence of the mixture of several compounds with diverse biological effects (CASTOLDI et al., 2018).

Alexander et al. (2020) showed that flavonoids isolated from Dipteryx lacunifera Ducke (garampara) are cytotoxic to different tumor cell lines, in addition to exhibiting antimalarial activity against Plasmodium falciparum, with parasitemia reduction greater than 80%. Conversely, amentoflavone, a compound isolated from Byrsonima intermedia (yellow murici), exhibited no toxicity against breast tumor cells (MCF-7), and estrogenic and antibacterial activity (CARDOSO; BAUAB; VARANDA, 2015).

The use of plants as a structuring agent in the development of polymeric nanocapsules with a lipid core was evaluated by Pires et al. (2020). The study showed that pequi oil (Caryocar brasiliense Cambess) has advantageous physicochemical and biological characteristics compared to commonly used medium-chain triglycerides, with lower cytotoxic effects of nanocapsules on V79 cells (Chinese hamster fibroblast) (PIRES et al., 2020).

In addition to cytotoxicity studies, an understanding of the mutagenic potential of medicinal plants is essential for user safety (WYREPKOWSKI et al., 2014). In fact, mutagenicity can cause genetic changes, which result in the formation of malignant tumors, at doses much lower than those necessary to cause acute toxicity (WYREPKOWSKI et al., 2014). Consequently, extracts obtained from Morinda citrifolia Linn. (noni), Hibiscus sabdariffa L. (hibiscus), Punica granatum L. (pomegranate), and Caesalpinia ferrea (pau-ferro) seem to be safe as they exhibit no mutagenic potential based on micronucleus (FERREIRA et al., 2017; GHELLER et al., 2017; MARTINS et al., 2019) and Ames tests (WYREPKOWSKI et al., 2014). In addition, noni, hibiscus, and pomegranate extracts exhibited antimutagenic effects, reducing the frequency of micronuclei in polychromatic erythrocytes (FERREIRA et al., 2017; GHELLER et al., 2017; MARTINS et al., 2019). Conversely, Caesalpinia peltophoroides Benth (sibipiruna) flower and leaf extracts did not exhibit similar chemoprotective effects, but displayed mutagenic action (SOUZA et al., 2019).

Natural compounds can also modulate the function of host physiological systems, modifying biological response to treatment or preventing disease (CHOPRA; DHINGRA, 2021). Therefore, the anti-inflammatory, immunomodulatory, antioxidant, and healing activities of natural products have been studied extensively.

The anti-inflammatory potential of Piper umbellatum L. (cow-foot leaf) and Cochlospermum regium (Mart. ex Schrank) (yellow cotton tree) was evaluated in intestinal and gastric inflammation models (ARUNACHALAM et al., 2019; ARUNACHALAM et al., 2020). Araunachalam et al. (2020) reported that the ethanolic extract of cow-foot leaves reduced the score of 2,4,6 trinitrobenzene sulfonic acid-induced ulcerative colitis in rats, with reduced ulcer areas (ARUNACHALAM et al., 2020). The anti-inflammatory action was associated with decreased levels of myeloperoxidase (MPO) activity, nitric oxide (NO), tumor necrosis factor alpha (TNF-a), interleukin 1 (IL-1), and lipid peroxidation, in contrast to increased catalase (CAT) activity, reduced glutathione (GSH) and superoxide dismutase (SOD), and consequently, decreased inflammatory infiltrate in the lesions (ARUNACHALAM et al., 2020). Ethanol extract of yellow cotton tree roots also showed a protective effect in the gastric ulcer model induced by acidified ethanol, piroxican, and stress, with reduced numbers of lesions, local inflammatory infiltrate, and MPO activity, and increased GSH and CAT (ARUNACHALAM et al., 2019). The anti-inflammatory and pro-osteogenic potential of phytocystatin extracted from Citrus sinensis (CsinCPI-2) (citrus) was observed in vitro and in vivo, with reduced TNF-a, IL-1, and inflammatory cysteine peptide (cathepsin K and B) levels (LEGUIZAMÓN et al., 2019).

The inflammation observed in diseases such as gastritis and colitis is a consequence of imbalance in pro-inflammatory factors, such as TNF-a, IL-1 and NO, and anti-inflammatory factors, such as IL-4, IL-10, as well as antioxidant defenses (ARUNACHALAM et al., 2019; ARUNACHALAM et al., 2020). The body's antioxidant defenses comprise enzymatic antioxidant compounds such as SOD and CAT, and non-enzymatic antioxidants such as GSH (LUIZ et al., 2020; SINHORIN et al., 2020). The compounds act synergistically to scavenge free radicals, as these molecules are highly reactive and can interfere with cellular integrity (LUIZ et al., 2020; SINHORIN et al., 2020). Homeostasis breakdown between oxidant and antioxidant mechanisms results in oxidative stress, which is a major cause of diseases such as cancer, diabetes, hypertension, and others (SINHORIN et al., 2020).

Plants are rich in antioxidant compounds such as tannins and flavonoids, which is a broad field for study (SINHORIN et al., 2020). The antioxidant potential of natural compounds can be initially screened using 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical capture or the reduction method, a rapid and easy-to-perform technique (QUEIROZ et al., 2015). The method was used to demonstrate the antioxidant potential of Equisetum hyemale L. (rough horsetail) (QUEIROZ et al., 2015), Morus nigra (black mulberry) (ZANCO; BONACORSI, 2017), and Cordia glabrata (louro branco) extracts (TOMAZELI et al., 2020). In general, the phytochemical analysis of the studied extracts demonstrated the presence of phenolic compounds such as flavonoids, terpenes, and tannins (QUEIROZ et al., 2015; TOMAZELI et al., 2020).

Another way of investigating the effects of natural compounds with an antioxidant profile is to induce oxidative stress, and potential damage, and then analyze enzymatic and non-enzymatic parameters (SINHORIN et al., 2020). Oxidative stress can be a consequence of toxicity induced by chemical agents such as acetaminophen and cyclophosphamide, or biological agents, such as the bacteria Helicobacter pylori and transplantable tumor cells, for example, in the case of Ehrlich's tumor (BARBOSA et al., 2018; BONACORSI et al., 2012; BONACORSI et al., 2013; CUNHA et al., 2019; GODOY et al., 2020; LUIZ et al., 2020; LUIZ et al., 2020 a; MAGALHÃES et al., 2019; PARACATU et al., 2014; PEREIRA et al., 2018; SINHORIN et al., 2020; SOUZA et al., 2017; TOMAZELI et al., 2020).

The ethanol extract of Protium heptaphyllum (breu) repaired oxidative stress induced by acetaminophen overdose in the liver and kidney of treated animals based on reduced tissue damage indicators such as thiobarbituric acid reactive substances (TBARS) and carbonylated proteins (SINHORIN et al., 2020). Reduced tissue damage was associated with antioxidant activity induced by the compounds present in the extract, mainly flavonoids, with CAT, SOD, GSH, ascorbic acid, and glutathione-S-transferase (GST) levels regulated (SINHORIN et al., 2020). In addition, extracts obtained from Trattinnickia rhoifolia (breu sucuruba) and Caesalpinia ferrea leaves exhibited hepatoprotective effects, reducing oxidative stress resulting from acetaminophen overdose and restoring the antioxidant defenses of treated animals (MAGALHÃES et al., 2019; SOUZA et al., 2017). Ethanol extract of stem bark of jatobá (Copaifera multijuga) also exhibited antioxidant activity, reversing the toxic effects of acetaminophen overdose in the liver, kidneys, and brain of the studied animals, mainly by regulating CAT, GSH, and ascorbic acid levels (PEREIRA et al., 2018). The antioxidant potential of jatobá extract appears to be due to tannins present in the plant, such as epicatechin and epiafzelechin (PEREIRA et al., 2018).

Cecropia distachya Huber (embaúba) (LUIZ et al., 2020 a), Carica papaya Linn (papaya tree) (LUIZ et al., 2020), and Cissus spinosa Cambess (cipó-de-arraia) leaf extracts (GODOY et al., 2020) exhibit antioxidant activity, attenuating oxidative stress induced by cyclophosphamide treatment and modulating CAT, GSH, and GST levels. The extracts also exhibit antimutagenic activity, with reduced frequency of micronucleated polychromatic erythrocytes (LUIZ et al., 2020; LUIZ et al., 2020 a; GODOY et al., 2020). However, toxic effects have also been observed in animals treated with such extracts, such as mutagenicity (GODOY et al., 2020), hepatotoxicity (LUIZ et al., 2020; LUIZ et al., 2020 a), increased TBARS, reduced SOD and GSH (LUIZ et al., 2020 a), and immunosuppression (LUIZ et al., 2020 a). Despite the identification of compounds with protective activities known as flavonoids, the observed toxicity may reflect the complexity of the components present, which may act differently according to concentration and exposure time (LUIZ et al., 2020; LUIZ et al., 2020 a). Capirona decorticans (capirona) can also have mutagenic activity, in contrast to the antimutagenic and hepatoprotective effects, with reduced carbonyl protein levels (BARBOSA et al., 2018).

The antioxidant potential of natural products can also be evaluated based on their effects Helicobacter pylori-induced neutrophil oxidative burst (BONACORSI et al., 2012; BONACORSI et al., 2013; PARACATU et al., 2014). H. pylori infection has been implicated in the pathogenesis of chronic gastritis, peptic ulcers and, more rarely, gastric cancer, both by direct infection effects and by the oxidative stress induced by inflammatory process products (BONACORSI et al., 2012). Bonacorsi et al. (2012) demonstrated that methanolic extract and purified phenolic compounds of Byrsonima crassa had dose-dependent suppressive effects on the oxidative burst of H. pylori-stimulated neutrophils, reducing reactive oxygen species (ROS) production by the cell. A similar effect was observed from Qualea parviflora, Q. multiflora, Alchornea triplinervia, Q. grandiflora, Anacardium humile, Davilla elliptica, Mouriri pusa, Byrsonima basiloba, A. glandulosa, and B. intermedia extracts, with CI50 values in the 27.2–56.8 mg mL-1 range (BONACORSI et al., 2013). In addition, alkyl caffeates of caffeic acid have anti-Helicobacter pylori activity and inhibitory effects on ROS generation by neutrophils (PARACATU et al., 2014). Caffeic acid is an important phenolic compound found in fruits, vegetables, wine, olive oil, and coffee (PARACATU et al., 2014).

The cellular proliferation of tumors is inversely proportional to lipid peroxidation, and decreased CAT, SOD, and GSH activity is considered a marker of malignant transformation (CUNHA et al., 2019). Cunha et al. (2019) demonstrated that treatment of animals with subcutaneous Ehrlich tumor with 200 mg mL-1 of ethanolic extract of jatobá (Copaiba multijuga) stem bark for 30 days increased CAT, GST, and GSH levels and reduced TBARS levels, protecting the animals from damage caused by tumor development.

Another interesting model for studying the antioxidant potential of natural products is the cigarette smoke-induced oxidative stress model (JAQUES et al., 2013). Cigarette smoke contains over 4,000 different chemical compounds and is a source of ROS and reactive nitrogen species (RNS) (JAQUES et al., 2013). Jaques et al. (2013) reported that curcumin (a polyphenol obtained from Curcuma longa L), both in the free and nanoencapsulated forms, can prevent memory impairment, redox imbalance, and changes observed in ATPase activities of the brain tissue of animals, protecting against tobacco-induced neurocognitive damage.

The antioxidant activities of plant extracts can be exploited as a natural metabolism modifier feed additive to improve pork carcass leanness and meat deterioration by lipid oxidation (GOIS et al., 2017; SBARDELLA et al., 2018). Meat from pigs fed a diet supplemented with Brazilian red pepper essential oil (Schinus terebinthifolius Raddi) and hop b-acid (Humulus lupulus L.) exhibited reduced lipid oxidation and TBARS levels, without affecting the physical characteristics of the meat (GOIS et al., 2017; SBARDELLA et al., 2018). Therefore, such plants can be used as natural food additives to improve the characteristics of stored meat.

In contrast to the described antioxidant activity of natural compounds, it is important to consider that ROS and RNS production by leukocytes also represent key host defense mechanisms against infections caused by bacteria, fungi, and parasites (ALBIERO et al., 2016; ALBIERO et al., 2020; CANTARINI et al., 2015; FIORI et al., 2017; RODRIGUES et al., 2019). Natural products can modulate immune effector cell functioning by activating their function, offering alternatives for preventing or curing neoplastic diseases or diseases caused by resistant microorganisms, or inhibiting them in case of chronic inflammatory diseases such as rheumatoid arthritis (ALBIERO et al., 2020; RODRIGUES et al., 2019). Therefore, the immunomodulatory action of natural compounds has been studied.

Cantarini et al. (2015) demonstrated that Orbignya phalerata Mart. (babassu) extract can stimulate the spontaneous release of superoxide by peripheral blood mononuclear phagocytes, in addition to increasing phagocytic and antibacterial activity against Escherichia coli. Superoxide anion release of human blood mononuclear cells was also enhanced by a microemulsion of Brazil nut oil (FIORI et al., 2017).

Immunostimulant action was observed in copaiba extracts (Copaifera multijuga) (ALBIERO et al., 2016; RODRIGUES et al., 2019). The ethanolic extract of this plant affected the development of Ehrlich's tumor in treated animals, reducing tumor mass by 45% and increasing the production of pro-inflammatory cytokines, such as IL-12p70, TNF-a, and interferon (IFN)-g, and the natural killer activity of splenic cells (ALBIERO et al., 2016; RODRIGUES et al., 2019).

In contrast, immunosuppressive action was observed in the synthetic derivative of coumarin (3-phenylcoumarin) (ALBIERO et al., 2020). Coumarins represent a widespread class of plant secondary metabolites that can be obtained by chemical synthesis with relative ease, and display various biological activities (RODRIGUES et al., 2019). Albiero et al. (2020) demonstrated that 3-PD-5 (6,7-Dihydroxy-3-[3',4'-methylenedioxyphenyl]-coumarin) has anti-inflammatory activity, reducing synovial neutrophil infiltration and joint swelling in animals with zymosan-induced arthritis. In addition, the compound reduced in vitro neutrophil activity, regulating ROS release, degranulation, neutrophil extracellular trap (NET) formation, and MPO activity (ALBIERO et al., 2020), so that it is a promising compound for the treatment of chronic inflammatory diseases.

Compounds capable of modulating the chronic inflammatory process can also inhibit tumor development (FURTADO et al., 2014). Most chronic liver diseases induce local inflammation, which, over time, favors a continuous tissue repair process with the accumulation of extracellular matrix proteins and the activation of hepatic stellate cells (FURTADO et al., 2014). Activated hepatic stellate cells have proliferative, migratory, and invasive capacity, being one of the main components of liver fibrosis and cirrhosis and, consequently, of hepatocellular carcinoma (BARRY et al., 2020). Furtado et al. (2014) demonstrated the protective effect of coffee and caffeine on liver fibrosis and carcinogenesis induced by DEN/CCl4 (diethynitrosamine/carbon tetrachloride). The study showed that consuming conventional coffee protected animals against the development of liver fibrosis, and instant coffee protected against chemical carcinogenesis, while caffeine (0.1%) was protective in both circumstances (FURTADO et al., 2014).

Another inflammation and tissue repair aspect is wound healing, such as that observed in burns and varicose ulcers (BOLINA-MATOS et al., 2013; FIGUEIREDO et al., 2020; PIRES et al., 2020a; VENAZZI et al., 2018). The wound healing process consists of an organized cascade of cellular and biochemical events that interact to regenerate and reconstitute injured tissue (FIGUEIREDO et al., 2020). It involves coagulation, inflammation, migration/proliferation, granulation, and tissue remodeling (FIGUEIREDO et al., 2020).

Figueiredo et al. (2020) observed that the topical use of Sorocea guilleminiana Gaudich (espinheira-santa falsa) leaf infusion helps in the treatment of skin wounds by stimulating fibroblast proliferation and lesion contraction, increasing type I collagen production and accelerating the inflammatory phase of the process. Pequi oil (Caryocar brasiliense) in lipid-core nanocapsules also healed skin wounds, reducing the diameter of the lesion in less time and stimulating type I collagen production (PIRES et al., 2020a). Type I collagen increases the mechanical resistance of the injured tissue, partly influencing the quality and degree of the wound healing process (FIGUEIREDO et al., 2020; PIRES et al., 2020a). Similarly, rubber tree (Hevea brasiliensis) natural latex biological membrane enhanced the healing of scalded skin in mice by stimulating neoangiogenesis and elastic fiber and collagen formation (BOLINA-MATOS et al., 2013). Aloe barbadensis Miller (aloe) gel showed promising results in the treatment of venous ulcers, improving vascularization and tissue growth (VENAZZI et al., 2018).

The biological effects of plant extracts in the modulation of metabolic diseases such as diabetes and obesity have also been studied (CUNHA; MUELLER, 2014; DENTZ et al., 2021; FARIA et al., 2018; FRANÇA et al., 2014; GIORDANI et al., 2015; GOMES et al., 2017; LUVIZOTTO et al., 2013; LUVIZOTTO et al., 2015; MELENDEZ-MARTINEZ et al., 2013; PIERINE et al., 2014). Diabetes is a global health problem, due to its high prevalence, and because the clinical course of the disease can lead to several impairments, such as vision loss, chronic renal disease, macro- and microvascular complications, and eventually result in physical incapacity or death (GIORDANI et al., 2015). It is now well established that the main cause of long-term diabetes damage is hyperglycemia, increased free fatty acids, and insulin resistance (GIORDANI et al., 2015; FRANÇA et al., 2014).

Cedella odorata (cedar), despite having low acute toxicity, exhibited promising activity in diabetes control by reducing glucose, triglyceride, and malondialdehyde (MDA) blood levels (GIORDANI et al., 2015). The effects seem to be associated with a potent inhibitory activity against a-glucosidase, and increased antioxidant defenses, such as SOD and glutathione peroxidase (GPx) (GIORDANI et al., 2015). Antidiabetic activity was also observed with the ethyl-acetate fraction of Trichilia catigu (catuaba) in a streptozotocin-induced type 1 diabetes model (GOMES et al., 2017). In the study, Gomes et al. (2017) reported that treatment with the fraction improved biochemical parameters of diabetic animals, such as blood glucose, alkaline phosphatase, alanine aminotransferase, and aspartate aminotransferase. The treatment stimulated b-pancreatic cell proliferation, increasing islets in number, area, and insulin density, and preserving renal tissue by reducing fibrosis formation (GOMES et al., 2017). Momordica charantia L and soybean compounds (protein and isoflavones) also showed the ability to prevent and/or attenuate diabetic metabolic disorders, e.g., by reducing blood viscosity (FRANÇA et al., 2014) and ameliorating glucose tolerance in tissue cells (FARIA et al., 2018).

Obesity is a highly prevalent disease in the world and a critical risk factor for the development of chronic and debilitating diseases (DENTZ et al., 2021). Several factors are involved in the pathogenesis of obesity, including behavioral and environmental factors, and the development of experimental high-fat diet models is a research strategy for the factors (DENTZ et al., 2021). High-energy diets, especially diets high in fat and carbohydrate, promote fat deposition in adipose tissues, contributing to the development of obesity (high-fat/sugar diet-induced obese rats) (DENTZ et al., 2021). Ethanolic extracts of hibiscus (Hibiscus sabdariffa) demonstrated clinical efficacy in the treatment of obesity and obesity-related diseases (DENTZ et al., 2021). The extracts reduced weight gain and mesenteric and visceral adipose tissue in obese animals, reducing blood glucose, IL-6, and leptin levels in adipose tissue and restoring adiponectin levels (DENTZ et al., 2021). White adipose tissue is a dynamic endocrine organ that secretes several types of adipokines and pro-inflammatory factors (LUVIZOTTO et al., 2013). Adiponectin is an essential adipokine for lipid and carbohydrate metabolism that is negatively correlated with obesity and insulin resistance (LUVIZOTTO et al., 2015). Leptin and resistin are pro-inflammatory adipokines that act in the pathophysiology of obesity-related complications such as atherosclerosis, tissue insulin resistance, and non-alcoholic fatty liver disease (LUVIZOTTO et al., 2013). The lycopene present in tomato extracts seems to reduce obesity-associated complications by reducing the inflammatory process via modulation of adipokines and the pro-inflammatory IL-6 and TNF-a cytokines (LUVIZOTTO et al., 2013; LUVIZOTTO et al., 2015; PIERINE et al., 2014; MELENDEZ-MARTINEZ et al., 2013).

Luvizotto et al. (2013) demonstrated that lycopene supplementation reduced the mRNA levels of IL-6, leptin, and resistin, in the adipose tissue and plasma of obese animals, but did not affect weight gain, adiposity, and insulin sensitivity. Lycopene appears to upregulate the mRNA expression of sirtuin 1 and FoxO1 (Forkhead box O1), which is critical for the transcriptional regulation of adiponectin (LUVIZOTTO et al., 2015). The anti-inflammatory effect of lycopene was also observed in the kidneys of obese animals, with reduced TNF-a production via RAGE (advanced glycation end products receptor) and consequent reduction of lipid peroxidation in the organ (PIERINE et al., 2014). However, although the compound also reduced liver inflammation in obese animals, lycopene supplementation increased liver lipogenesis by modulating the transcription of enzymes involved in the process (MELENDEZ-MARTINEZ et al., 2013).

The effect of yerba mate (Ilex paraguariensis) in controlling weight gain in rats was evaluated, with the expected effects not observed (CUNHA; MUELLER, 2014).

The effects of natural products on weight gain have been evaluated based on other aspects, such as livestock performance, for example, the performance the effect of compounds on fermentation processes in the rumen of farm animals (FRANCO et al., 2020). Rumen microbiota degrade dietary components providing not only short-chain fatty acids and proteins, but also ammonia and methane gas, which can affect weight gain (FRANCO et al., 2020). Therefore, plant extracts are potential alternatives for modifying the rumen environment, and modulating microbial populations (FRANCO et al., 2020). Castor seed extract (Ricinus communis L) is rich in ricin, a toxic protein that irreversibly inactivates the ribosomes of eukaryotic cells (OLIVEIRA et al., 2010). Oliveira et al. (2010) demonstrated that crude castor bean bran extract inhibits ruminal microbial growth, although the ruminal microbiota can degrade ricin in in vitro conditions. However, detoxification with alkali treatment increases the rumen microbial specific growth rate in vitro (OLIVEIRA et al., 2010). Despite the effect, its action as a ruminal fermentation modifier has not been confirmed (OLIVEIRA et al., 2010).

Cairo et al. (2018) reported that supplementing the diet of weaned pigs with Schinus terebinthifolius Raddi (red pepper) modulated the gut microbiota by increasing Lactobacillus and reducing enterobacterium counts, without affecting organ performance or weight. In addition, animals treated with the supplement had lower incidence of diarrhea, demonstrating the beneficial effect of the Lactobacillus microbiota in controlling the colonization of potentially pathogenic bacteria and in optimizing the immune response of animals (CAIRO et al., 2018). Similar beneficial effects were not observed following supplementation of the diet of grazing beef cattle with dried cashew processing products (SOUZA et al., 2020). Cashew-derived products consist of the fibrous fraction obtained after the extraction of cashew oil (Anacardium occidentale L.) and was evaluated as a substitute for maize in animal feed (SOUZA et al., 2020). However, the tannins present in the supplement seem to affect the performance of animals since the treatment reduced intake, apparent diet digestibility, microbial nitrogen synthesis, and nitrogen retention (SOUZA et al., 2020). Similarly, the replacement of maize with dried whole nut of cupuaçu (Theobroma grandiflorum) in concentrate supplements for grazing cattle is not recommended because it reduces supplement and pasture intake, microbial synthesis efficiency, and nitrogen balance, and consequently, animal liveweight gain (MENESES et al., 2020). The same effect was observed by Souza et al. (2017) with alkaline-treated Jatropha curcas L. meal supplementation for grazing dairy cows. The use of noni (Morinda citrifolia) as a phytogenic additive in feed for confined lambs showed no promising results, with no effects on ingestive behavior or physiological variables (GERON et al., 2019).

In addition to studies evaluating the potential effect of products obtained from plants on the performance of farm animals and in meat conservation, natural products are being evaluated for their potential to improve the structural quality of meat (MONTESCHIO et al., 2019). Monteschio et al. (2019) reported that supplementing clove (Syzygium aromaticum) and rosemary (Rosmarinus officinalis) essential oils, or an encapsulated mixture of their main active compounds (eugenol, thymol, and vanillin), in the finishing diets of Nellore heifers increased sarcomere length, soluble collagen content, and reduced type III collagen, but had no effect on meat muscle fiber types and chemical composition. Overall, the characteristics resulted in meat tenderness modulation and may be a consequence of rumen metabolism and antioxidant defenses induced by bio-compounds (MONTESCHIO et al., 2019).

Other studies evaluated the antinociceptive, antidepressant, and anxiogenic activities of natural products obtained from plants. Extracts and amines (N-[7-(3´-4´-methylenedioxyphenyl)-2(Z),4(Z)-

heptadienoyl] pyrrolidine and N-[7-(3´-4´-methylenedioxyphenyl)-2(E),4(E)-heptadienoyl] pyrrolidine) obtained from Piper amalago (jaborandi) reduced pain on mechanical stimulation, latency time to pain by heating, and knee edema in acute and chronic pain animal models, showing the antihyperalgesic, antinociceptive and anti-arthritic activities of the natural products analyzed (ARRIGO et al., 2016). Using experimental models for hyperalgesia (spared nerve injury and formalin) and depression (clonidine), Santos et al. (2017) stated that Salvia lachnostachys Benth (sage) leaf extract has antinociceptive, antihyperalgesic, and antidepressant effects, and that the activity must be, at least in part, attributed to the presence of fruticuline A. Melo et al. (2013) reported that extracts and b-amyrin acetate obtained from Tabernaemontana solanifolia (mata-pasto) have anxiogenic effects in rats tested in the elevated plus-maze, increasing the number of entries into and time spent in closed arms.

Considering the biological effects attributed to many compounds isolated from plant products, few studies have evaluated the oral absorption of such products. Mauro et al. (2019) showed that copalic and kaurenoic acid from Copaifera langsdorffii (copaiba) oleoresin has moderate intestinal permeability, and passive diffusion is the main mechanism driving its oral absorption. Such findings support the popular use; however, the stomach pH can degrade the compounds, so that an enteric-coated dosage form is required to avoid chemical instability in the stomach (MAURO et al., 2019).

Finally, a study evaluated the safety of a herbal product called Elixir Paregórico®, which consists mainly of P. somniferum (opium poppy) and is used by Brazilians for the treatment of diarrhea, demonstrating that its use four times a day for 10 days is safe for patients (MORAES et al., 2008). Caetano et al. (2016) carried out a literature review on yacon root (Smallanthus sonchifolius), demonstrating the benefits of fructooligosaccharides present in the plant in modulating the intestinal microbiota and metabolic pathways related to glucose and lipid homeostasis, being an important dietary supplement for preventing and treating chronic diseases, such as colon cancer, diabetes, and obesity. In addition, Cavalheiro and Guarim-Neto (2018) conducted an ethnobotanical study in the Aldeia Velha Community, Chapada dos Guimarães, Mato Grosso, Brazil, and described 72 species of medicinal plants used by women in the community for the treatment of inflammatory, respiratory, digestive, metabolic, and genitourinary diseases, seven of which have been selected for their biotechnological potential.

Therefore, this review highlights the potential benefits of the studies conducted by UFMT-Sinop researchers, demonstrating their relevance in the area of bioprospecting in the state. The potential benefits are reinforced by studies by Cavalheiro and Guarim-Neto (2018).

In addition to studies on natural compounds obtained from plants, research has been conducted on the biological effect of compounds produced by microorganisms.

The biological effect of natural products obtained from microorganisms

The bibliographic survey on the biological effect of natural products from microorganisms yielded 26 articles, including a literature review. In general, the studies involved the evaluation of biological effects on tumor development, obesity, candidiasis, farm animal performance, and phytopathogen control in different cultures.

Natural products from microorganisms are structurally diverse and thus represent a rich source for the commercial production of drugs used for human medicine, animal health, as well as plant crop protection (CHOPRA; DHINGRA, 2021). Microorganisms can inhabit niches as free-living organisms or in symbiotic associations with multicellular hosts or other unicellular organisms in various ecological habitats, from the deepest seas to arid deserts and the guts of the multicellular organisms, in addition to establishing parasitic systems (ALAM et al., 2021). According to estimates, approximately less than 1% of microorganisms in ecosystems are accessible through traditional culture techniques, and more than 99% have not yet been identified, so that they are a promising source of innovative natural products (ALAM et al., 2021).

Queiroz et al. (2017) showed that levan, a (2-6)-b-D-fructan secreted by halophilic bacterium Halomonas smyrnensis (AAD6T), had time- and concentration-dependent antiproliferative activity in MCF-7 breast cancer cell, and the effect was associated with an increase in cell apoptosis, oxidative stress, and p53 and p27 gene expression. Antiproliferative activity was also observed in MCF-7 breast cancer cells with botryosphaeran and lasiodiplodan, fungal exocellular b-glucans obtained from Botryosphaeria rhodina and Lasiodiplodia theobromae, respectively (QUEIROZ et al., 2015a). In the study, the authors demonstrated that the antiproliferative effect of b-glucans is mediated by AMPK (AMP-activated protein kinase) and FOXO3a (Forkhead transcription factor 3a) activation, inducing cell death by increasing oxidative stress and by the expression of tumor suppressors and apoptotic genes, such as p53, p27, and Bax (QUEIROZ et al., 2015a).

The antitumor effects of botryosphaeran were also evaluated in the in vivo development of Walker-256 tumor in obese (high-fat/sugar diet-induced rats) and non-obese animals (COMIRAN et al., 2021; GERALDELI et al., 2020; GERALDELI et al., 2020 a). Oral treatment with botryosphaeran for 15 days reduced tumor development in non-obese animals and cancer cachexia syndrome (GERALDELI et al., 2020). The effects are associated with improved metabolic parameters, regulating glycemic levels, decreasing weight-loss, and correcting macrocytic anemia, as well as inducing apoptosis with increased Bax pro-apoptotic protein expression in tumor tissue (GERALDELI et al., 2020). In obese animals, reduced tumor development and cachexia were accompanied by reduced mesenteric adipose tissue, insulin resistance, and modulated total cholesterol levels (COMIRAN et al., 2021; GERALDELI et al., 2020 a). Botryosphaeran also increased FOXO3a activity directly in Walker-256 bearing tumor tissue, contributing to decreased tumor proliferation (GERALDELI et al., 2020 a). Silva et al. (2018) showed that botryosphaeran reduces obesity, hepatic steatosis, dyslipidemia, insulin resistance, glucose intolerance, and periepididymal and mesenteric adipose tissue accumulation in obese rats, and the effects were, at least in part, associated with reduced feed intake and higher AMPK and FOXO3a expression in adipose tissue.

Polysaccharides obtained from edible mushrooms, such as Lentinus edodes (shiitake) and Agaricus brasiliensis (sun mushroom), are also widely studied for their biological effects (LESSNA et al., 2015; LIMA et al., 2010; LIMA et al., 2013; MARTINS et al., 2008). Martins et al. (2008) reported that the polysaccharide-rich fraction of A. brasiliensis increased the microbicidal activity of macrophages against Candida albicans, stimulating hydrogen peroxide production and mannose receptor expression by peritoneal macrophages, which is important for non-opsonized microorganism attachment and phagocytosis. In addition, treatment of animals with the extract enhanced the clearance of C. albicans during the first 6 h after experimental intraperitoneal infection (MARTINS et al., 2008).

Considering the nutritional and medicinal value of mushrooms and their widespread use by populations, Lessna et al. (2015) evaluated the effect of chronic use of sun mushroom extracts (A. brasiliensis) on the cardiac morphology of mice, and reported no morphological or structural changes that might suggest organ toxicity. The storage of natural extracts is another critical aspect in the context of medicinal use by populations. Lima et al. (2010) reported that the storage of L. edodes powder at room temperature or at -20 ºC reduced the antigenotoxic effects, when compared with fresh powder, increasing the frequency of bone marrow micronucleated polychromatic erythrocytes induced by ethyl-N-nitrosurea (LIMA et al., 2010). In addition, animals pre-treated with extract prepared with powder stored at -20 ºC exhibited increased basal DNA damage when compared with the untreated control animals, demonstrating that storage can alter the biological properties of bio-compounds and, in such a case, result in genotoxic effects (LIMA et al., 2010). The same research group demonstrated that L. edodes extracts facilitate the removal of circulating erythrocytes with intraerythrocytic inclusions, such as micronuclei and protozoa, from phagocytosis by splenic macrophages, in a process known as pitting (LIMA et al., 2013).

As for the probiotic action of microorganism compounds on the performance of farm animals, Machado et al. (2020) showed that the supplementation of broiler feed with xylanase (obtained from Pichia pastoris fungus) and probiotics (Colostrum Mix, Biocamp, composed of competitive exclusion probiotic microorganisms and probiotic components obtained from the intestinal microbiota of specific pathogen-free adult poultry, BR) stimulated weight gain and feed conversion by about 17.5%. The authors reported that the increased performance resulted from the modulating effect on the ileal microbiota of the animals, with an increased frequency of Lactobacillales and reduced pH and intestinal viscosity (MACHADO et al., 2020). Together, the effects increased intestinal functioning, digestion, and nutrient absorption by the animals (MACHADO et al., 2020).

The beneficial effect of probiotics in the diet of lactating dairy cows challenged with dietary aflatoxin B1 was also observed (JIANG et al., 2018). The combination of sodium bentonite clay and Saccharomyces cerevisiae fermentation products reduced aflatoxin transfer from diet to milk and also reduced the negative effects of the toxin on the body of cows, improving rumen fermentation and increasing milk protein production and concentration (JIANG et al., 2018). In contrast, the benefits were not observed in tambaqui fish challenged with transport stress after the use of a probiotic based on Bacillus spp. supplemented in the diet and dissolved in water (FERREIRA et al., 2014).

In agricultural research, the biological control effects of compounds produced by microorganisms, mainly fungi and bacteria, against orange, maize, passion fruit, and soybean pests, as well as their growth-promoting activities, have been evaluated (ANTUNES et al., 2020; BULHÕES; MELO; SHIOMI, 2019; FERRARI; VALIATI; SHIOMI, 2012; GONÇALVES et al., 2015; MURATE et al., 2015; KHOSHRU et al., 2020; OLIVEIRA et al., 2016; OLIVEIRA et al., 2019; SHIOMI; FERREIRA; MELO, 2017; SHIOMI; MELO; MINHONI, 2015; VALIATI; FERRARI; SHIOMI, 2012; ZAMBIAZZI et al., 2011; ZAMBIAZZI et al., 2016).

The ethyl-acetate fraction of the culture supernatant of Pseudomonas sp. (strain LN) exhibited antimicrobial activity against the bacterium Xanthomonas axonopodis (pv. citri 306 strain), which causes citrus canker, reducing orange leaf lesion area by 40% without phytotoxicity (MURATE et al., 2015; OLIVEIRA et al., 2016). The same research group reported that semi-purified metabolites of the fraction (natural organocopper antibiotic compound and phenazine-1-carboxamide) can reduce the extracellular polysaccharide layer on the surface of infected leaves (OLIVEIRA et al., 2016). The presence of the biofilm on the plant surface facilitates the colonization of deep leaf tissues and is related to the virulence of the bacteria (OLIVEIRA et al., 2016). Therefore, the compounds obtained from Pseudomonas culture can act directly by killing the bacteria or indirectly by reducing its inoculum potential (OLIVEIRA et al., 2016).

Bacterial isolates in biofertilizers produced from bovine and swine manure also demonstrate fungicidal activity against anthracnose in passion fruit (Colletotrichum gloeosporoides) (BULHÕES; MELO; SHIOMI, 2019), Penicillium sp. in orange (FERRARI; VALIATI; SHIOMI, 2012), white mold in soybean (Sclerotinia sclerotiorum) (SHIOMI; FERREIRA; MELO, 2017), and in in vitro control of Aspergillus sp. (VALIATI; FERRARI; SHIOMI, 2012). Shiomi et al. (2015) reported that endophytic bacteria reduce the severity of leaf spot by Exserohilum turcicum in maize. In addition, volatile compounds produced by saprobic conidial fungi from the Amazon region (Beltrania rhombica, Brachysporiella sp., Dictyochaeta sp., Gonytrichum sp.) have inhibitory activity against phytopathogens, reducing the formation of survival structures and sclerotia in the studied fungi (OLIVEIRA et al., 2019). The biological control effects of fungus Beauveria bassiana against corn earworm (Helicoverpa zea) and soybean brown stink bug (Euschistus heros) were evaluated in vitro, with highly promising results of 100% mortality (ZAMBIAZZI et al., 2011; ZAMBIAZZI et al., 2016). In addition, Antunes et al. (2020) showed that the use of Bacillus subtilis and salicylic acid are potential strategies of maintaining the physicochemical quality of tomatoes in cold storage via the promotion of cell wall maintenance and membrane integrity.

Fungi and bacteria can also promote plant growth by modulating their responses to different stress factors, such as temperature, humidity, and pathogens (GONÇALVES et al., 2015; KHOSHRU et al., 2020). This plant growth-promoting activity has been described mainly for fungi, such as Glomus clarum, and bacteria, such as Rhizobium sp. (GONÇALVES et al., 2015; KHOSHRU et al., 2020).

Therefore, microorganism bioprospecting has also been a prominent area of research at UFMT-Sinop, with studies covering several fields, such as health and agriculture.

Studies on the biological effect of natural products obtained from animals

Studies on the biological effects of natural products obtained from animals focused on the evaluation of propolis produced by bees and venom produced by frogs of the genera Rhinella and Rhaebo, with a total of 11 articles.

Propolis extracts have been evaluated for their antifungal and cytotoxic activity (CAMARGO et al., 2013; GREGOLIN et al., 2019; LORINI et al., 2018; PEREIRA et al., 2013; ZANATTO; BONALDO; PEREIRA, 2018). Ethanol extracts of propolis from different regions of Brazil exhibited antifungal activity against Fusarium proliferatum (causal agent of diseases in several types of plants and mycotoxin production in fruits and grains), reducing macrolide sporulation and mycelial growth (GREGOLIN et al., 2019). In the study, green propolis from Minas Gerais (Brazil) exhibited strong fungitoxic and antioxidant activity, with considerable levels of quercitin and kaempferol flavonoids (GREGOLIN et al., 2019). Red propolis from Paraíba (Brazil) also inhibited the germination of Aspergillus flavus spores isolated from Brazil nut, and this activity seems to be associated with higher quercitin, apigenin, and kaempferol levels (LORINI et al., 2018). Therefore, the use of propolis in controlling microorganisms in food is promising.

The capacity of propolis to control diseases in soybean has also been evaluated (PEREIRA et al., 2013; ZANATTO; BONALDO; PEREIRA, 2018). Ethanol extract of propolis was efficient in controlling foliar diseases caused by Peronospora manshurica (mildew) and Corynespora cassiicola (target spot), increasing crop productivity by up to 23%, by reducing disease severity (target spot) and maintaining water content in plant tissues (PEREIRA et al., 2013; ZANATTO; BONALDO; PEREIRA, 2018). The benefits seem to result from a combination of the direct fungicidal activity of phenolic compounds present in propolis and indirect effects mediated by the physical protection by waxes and solid substances present in the compound that prevent pathogen entry (PEREIRA et al., 2013).

Brown propolis is the main type of propolis in Cuba, and its main component is nemorosone, a naturally occurring polycyclic polyprenylated acylphloroglucinol present in Clusia rosea floral resin (CAMARGO et al., 2013). Camargo et al. (2013) showed that the isolated compound has antiestrogenic activity, reducing MCF-7 cell (human MCF-7 BUS breast cancer cell) proliferation induced by estradiol, with no genotoxicity, so that it is a promising compound for application in the treatment of breast cancer.

Skin secretions and venom of amphibians are also fascinating sources of active compounds, such as peptides, alkaloids, bufadienolides, biogenic amines, and proteins (FERREIRA et al., 2013). Ferreira et al. (2013) reported that extracts obtained from the venom of Rhinella marina and Rhaebo guttatus are cytotoxic to tumor (leukemia, colon carcinoma, ovarian carcinoma, and glioblastoma) and non-tumor cells (human peripheral blood mononuclear cells). The effect seems to be a consequence of the antiproliferative action of the extract, which induce cell cycle arrest, and is not due to direct damage to the cell plasma membrane (FERREIRA et al., 2013). The cytotoxic activity of the extracts was also observed in other cell types (BANFI et al., 2016; GARCIA et al., 2019; OLIVEIRA et al., 2019a). In such a case, the apoptotic action is due to calcium level modulation, with Na, K-ATPase, and Ca+2 ATPase inhibition, and caspase 3 and 9 activation (GARCIA et al., 2019). In addition, other activities have been described, such as antimutagenic, genotoxic (OLIVEIRA et al., 2019a), and antiplasmodial (Plasmodium falciparum strain) activities (BANFI et al., 2016). The authors of the studies above identified some candidate compounds, such as telocinobufagin, marinobufagin, bufalin, resibufogenin, marinobufotoxin, and dehydrobufotenin (BANFI et al., 2016; FERREIRA et al., 2013; GARCIA et al., 2019).

Machado et al. (2018) evaluated the cytotoxic activity of marinobufagin obtained from the anuran R. marina on different cell lines and on meristematic cells of Allium strain. The authors reported high cytotoxicity against human tumor cells but not against normal murine and human cells (MACHADO et al., 2018). Marinobufagin-treated human leukemia cells exhibited increased numbers of apoptotic cells, with DNA fragmentation, phosphatidylserine externalization, binucleation, nuclear condensation, and cytoplasmatic vacuoles (MACHADO et al., 2018). Antiproliferative effects were also observed in A. cepa root and seem to be the result of cell cycle arrest and chromosomal changes in meristematic cells (MACHADO et al., 2018). Furthermore, clastogenic effects were observed only in the meristematic cells of Allium cepa, with no genotoxicity to human leukemia cells (HL-60) and human blood cells (MACHADO et al., 2018).

Compounds present in methanolic extracts of R. marina and R. guttatus venom also modulate phytoalexin and pathogenesis-related protein expression, which induce biochemical and physiological changes in plants during defense responses, protecting the plants against subsequent infection (RAASCH-FERNANDES et al., 2019). In general, the authors demonstrated that compounds obtained from R. marina can positively influence defense responses in soybeans and beans, while compounds from R. guttatus inhibit such responses in soybean (RAASCH-FERNANDES et al., 2019).
Therefore, compounds obtained from animals also have biotechnological potential, highlighting a promising field research in the campus.

Conclusion

The present bibliographic survey highlights the relevance of the research carried out at the UFMT-Sinop campus, with studies conducted on diverse types of natural products, with analyses of a wide variety of biological effects with biotechnological application potential in human and animal health as well as agriculture. The researchers benefit from the biodiversity resident in the state, which facilitates the study of natural products from plants and animals obtained from the Amazon Biome, Cerrado, and Pantanal

Acknowledgment

This study was supported by the Universidade Federal de Mato Grosso – Edital de Apoio à Pesquisa (2021).

References

ALAM, K., ABBASI, M.N., HAO, J., ZHANG, Y., LI, A. Strategies for natural products discovery from uncultured microorganisms. Molecules. Vol. 26, p 2977, 2021. DOI: 10.3390/molecules26102977

ALBIERO, L.R., ANDRADE, M.F., MARCHI, L.F., LANDI-LIBRANDI, A.P., FIGUEIREDO-RINHEL, A.S.G., CARVALHO, C.A., KABEYA, L.M., OLIVEIRA, R.D.R., AZZOLINI, A.E.C.S., PUPO, M.T., EMERY, F.S., LUCISANO-VALIM, Y.M. Immunomodulating action of the 3-phenylcoumarin derivative 6,7-dihydroxy-3-[3',4'-methylenedioxyphenyl]-coumarin in neutrophils from patients with rheumatoid arthritis and in rats with acute joint inflammation. Inflammation Research. Vol. 69, p 115-130, 2020. DOI: 10.1007/s00011-019-01298-w

ALBIERO, L.R., NERY, E.F., DALAZEN, J.C.S., KELLY, T.O., PEREIRA, D.L., SINHORIN, V.D.G., KANENO, R., CASTOLDI, L. Ethanolic extracts of Copaifera multijuga inhibits the subcutaneous growth of Ehrlich carcinoma in swiss mice. IOSR Journal of Pharmacy and Biological Sciences. Vol. 11, p 30-38, 2016. DOI: 10.9790/3008-1105033038

ALEXANDRE, L.S., OLIVEIRA, M.S., DITTZ, D., SOUSA, R.W.R., FERREIRA, P.M.P., PESSOA, C., VAROTTI, F.P., SANCHEZ, B.A.M., BANFI, F.F., CHAVES, M.H., JÚNIOR, G.M.V. Flavonoids, cytotoxic, and antimalarial activities of Dipteryx lacunifera. Revista Brasileira de Farmacognosia. Vol. 30, p 544-550, 2020. DOI: 10.1007/s43450-020-00082-w

ALMEIDA, F.A., FONSECA, W.L., LEITE, M.L.T., RAMBO, T.P., PEREIRA, F.F., PETTER, F.A., OLIVEIRA, A. M., CARVALHO, R.M., NETO, F.A. Toxicity of plant extracts to Meloidogyne incognita in tomato plants. International Journal of Current Research. Vol. 8, p 38476-38481, 2016. https://www.journalcra.com/article/toxicity-plant-extracts-meloidogyne-incognita-tomato-plants

ANTUNES, D.T., ZANUZO, M.R., JÚNIOR, F.F., JÚNIOR, S.S., DIAMANTE, M.S., DALBIANCO, A.B., NASCIMENTO, M.S.P. Postharvest storage of Italian tomatoes using Bacillus subtilis and salicylic acid. International Journal of Development Research. Vol. 10, p 37983-37988, 2020. DOI: 10.37118/ijdr.19319.07.2020

ARRIGO, J.S., BALEN, E., JÚNIOR, U.L., MOTA, J.S., IWAMOTO, R.D., BARISON, A., SUGIZAKI, M.M., KASSUYA, C.A.L. Anti-nociceptive, anti-hyperalgesic and anti-arthritic activity of amides and extract obtained from Piper amalago in rodents. Journal of Ethnopharmacology. Vol. 179, p 101-109, 2016. DOI: 10.1016/j.jep.2015.12.046

ARUNACHALAM, K., DAMAZO, A.S., MACHO, A., LIMA, J.C.S., PAVAN, E., FIGUEIREDO, F.F., OLIVEIRA, D.M., CECHINEL-FILHO, V., WAGNER, T.M., MARTINS, D.T.O. Piper umbellatum L. (Piperaceae): Phytochemical profiles of the hydroethanolic leaf extract and intestinal anti-inflammatory mechanisms on 2,4,6 trinitrobenzene sulfonic acid induced ulcerative colitis in rats.

Journal of Ethnopharmacology. Vol. 254, 13 pages, 2020. DOI: 10.1016/j.jep.2020.112707

ARUNACHALAM, K., DAMAZO, A.S., PAVAN, E., OLIVEIRA, D.M., FIGUEIREDO, F.F., MACHADO, M.T.M., BALOGUN, S.O., SOARES, I.M., BARBOSA, R.S., ALVIM, T.S., ASCÊNCIO, S.D., MARTINS, D.T.O. Cocholospermum regium (Mart. Ex Schrank) Pilg.: Evaluation of chemical profile, gastroprotective activity and mechanism of action of hydroethanolic extrac of its xylopodium in acute and chronic experimental models. Journal of Ethnopharmacology. Vol. 233, p 101-114, 2019. DOI: 10.1016/j.jep.2019.01.002

BANFI, K.S., GUEDES, C.R., ANDRIGHETTI, A.C., AGUIAR, B.W., DEBIASE, J.C., NORONHA, D.J., RODRIGUES, G.M.V., JUNIOR, SANCHEZ, B.A.M. Antiplasmodial and cytotoxic activities of toad venoms from Southern Amazon, Brazil. Korean Journal of Parasitology. Vol. 54, p 415-421, 2016. DOI: 10.3347/KJP.2016.54.4.415

BARBOSA, F.G., SUGUI, M.M., SINHORIN, V.D.G., BICUDO, R.C., MOURA, F.R., SINHORIN, A.P. First phytochemical and biological study of the ethanolic extract from leaves of Capirona decorticans (Rubiaceae). Acta Amazonica. Vol. 48, p 338-346, 2018. DOI: 10.1590/1809-4392201703483

BARREIRO, E.J., BOLZANI, V.S. Biodiversidade: fonte potencial para a descoberta de fármacos. Química Nova. Vol. 32, p 679 – 688, 2009. DOI: 10.1590/S0100-40422009000300012

BARRY, A.E., BALDEOSINGH, R., LAMM, R., PATEL, K., ZHANG, K., DOMINGUEZ, D.A., KIRTON, K.J., SHAH, A.P., DANG, H. Hepatic Stellate Cells and Hepatocarcinogenesis. Frontiers in Cell and Developmental Biology. Vol. 8, article 709, 2020. DOI: 10.3389/fcell.2020.00709

BOLINA-MATOS, R.S., ALVES, P.H.M., RICI, R.E.G., FAVARON, P.O., LIBERTI, E.A. Effects of the natural latex biomembrane (Hevea brasiliensis) in wistar rat skin submitted to body thermal injury by scalding. Revista Brasileira de Queimaduras. Vol. 12, p 270-277, 2013. http://www.rbqueimaduras.com.br/related-content/174/pt-BR

BONACORSI, C., FONSECA, L.M., RADDI, M.S.G., KITAGAWA, R.R., VILEGAS, W. Comparison of Brazilian plants used to treat gastritis on the oxidative burst of Helicobacter pylori-stimulated neutrophil. Evid Based Complement Alternat Med. Vol. 2013, 8 pages, 2013. DOI: 10.1155/2013/851621

BONACORSI, C., RADDI, M.S.G., FONSECA, L.M., SANNOMIYA, M., VILEGAS, W. Effect of Byrsonima crassa and phenolic constituents on Helicobacter pylori-induced neutrophils oxidative burst. International Journal of Molecular Sciences. Vol. 13, p 133-141, 2012. DOI: 10.3390/ijms13010133

BULHÕES, C.C., BONALDO, S.M., SANTOS, B.T, TRENTO, R.A. Alternative products in control of Anthracnose (Colletotrichum gloeosporioides), verrucose (Cladosporium herbarum) and bacterial blight (Xanthomonas campestres pv. passiflorae) in passion fruit in the north of Mato Grosso. Campo Digital: Rev. Ciências Exatas e da Terra e Ciências Agrárias. Vol. 7, p 12-19, 2012. https://www.researchgate.net/publication/281715484_ALTERNATIVE_PRODUCTS_IN_CONTROL_OF_ANTHRACNOSE_Colletotrichum_gloeosporioides_VERRUCOSE_Cladosporium_herbarum_AND_BACTERIAL_BLIGHT_Xanthomonas_campestris_pv_passiflorae_IN_PASSION_FRUIT_IN_THE_NORTH_O

BULHÕES, C.C., MELO, I.S., SHIOMI, H.F. Biocontrol of anthracnose on yellow passion fruits by antagonic bacteria to plant pathogens. Scientific Electronic Archives. Vol. 12, p 10-15, 2019. DOI: 10.36560/1242019733

CAETANO, B.F.R., MOURA, N.A., ALMEIDA, A.P.S., DIAS, M.C., SIVIERI, K., BARBISAN, L.F. Yacon (Smallanthus sonchifolius) as a food supplement: Health-promoting benefits of fructooligosaccharides. Nutrients. Vol. 8, p 436, 2016. DOI: 10.3390/nu8070436

CAIRO, P.L.G., GOIS, F.D., SBARDELLA, M., SILVEIRA, H., OLIVEIRA, R.M., ALLAMAN, I.B., CANTARELLI, V.S., COSTA, L.B. Effects of dietary supplementation of red pepper (Schinus terebinthifolius Raddi) essential oil on performance, small intestinal morphology and microbial counts of weanling pigs. Journal of Science Food Agriculture. Vol. 98, p 541-548, 2018. DOI: 10.1002/jsfa.8494

CAMARGO, M.S., PRIETO, A.M., RESENDE, F.A., BOLDRIN, P.K., CARDOSO, C.R.P., FERNANDEZ, M.F., MOLINA-MOLINA, J.M., OLEA, N., VILEGAS, W., CUESTA-RUBIO, O., VARANDA, E.A. Evaluation of estrogenic, antiestrogenic and genotoxic activity of nemorosone, the major compound found in brown Cuban propolis. BMC Complementary and Alternative Medicine. Vol. 13, 8 pages, 2013. DOI: 10.1186/1472-6882-13-201

CANTARINI, D.G., ROSA, J.C.D., VENTURINI, L.G.R., SILVA, J.P.M.O., HONORIO-FRANÇA, A.C., FRANÇA, E.L. Immunomodulation of human blood phagocytes by Orbignya phalerata Mart. plus IFN-g and TGF-b cytokines. European Journal of Medicinal Plants. Vol. 6, p 167-174, 2015. DOI: 10.9734/EJMP/2015/14760

CARDOSO, C.R.P., BAUAB, T.M., VARANDA, E.A. Quality control and evaluation of pharmacological activity of Byrsonima intermedia extract and amentoflavone. SaBios: Revista Saúde e Biologia. Vol. 10, p 35-42, 2015.

file:///Users/lindseycastoldi/Downloads/1850-Texto%20do%20Artigo-10040-3-10-20151208.pdf

CARLOS, M.M., SCHWAN-ESTRADA, K.R.F., ITAKO, A.T., BONALDO, S.M., MESQUINI, R.M., CARVALHO, J.B., STANGARLIN, J.R. Effect of crude extract and essential oil of Achillea millifolium L. on the in vitro development of Corynespora cassiicola and protection of cucumber against Corinespora leaf spot. Arquivos do Instituto Biologia. Vol. 77, p 309-316, 2010. DOI: 10.1590/1808-1657v77p3092010

CARVALHO, J.B., SCHWAN-ESTRADA, K.R.F., BONALDO, S.M., CRUZ, M.E.S., CARLOS, M.M., STANGARLIN, J.R. Fungitoxicidade de Cymbopogon citratus e Cymbopogon martinii a Colletotrichum gloeosporioides em frutos de pimentão. Revista Brasileira de Plantas Medicinais. Vol. 10, p 88-93, 2008. https://www1.ibb.unesp.br/Home/Departamentos/Botanica/RBPM-RevistaBrasileiradePlantasMedicinais/artigo13_v10_n1_p88a93.pdf

CASTOLDI, L., ALBIERO, L.R., NERY, E.F., KELLY, T.O., DALAZEN, J.C.S., MASOCHINI, R.G. Evaluation of in vitro cytotoxic effects of Específico Pessoa phytotherapic tincture on Ehrlich tumor cells and mice spleen cells. Fronteiras: Journal of Social, Technological and Environmental Science. Vol. 9, p 458-472, 2020. a. DOI: 10.21664/2238-8869.2020v9i1.p458-472

CASTOLDI, L., KELLY, T.O., ALBIERO, L.R., NERY, E.F., DALAZEN, J.C., VALLADÃO, D.M.S. Evaluation of the in vitro cytotoxic effects of carvoeiro leaf extracts [Callisthene fasciculata (Spr.) Mart.]. Scientific Electronic Archives. Vol. 11, p 124-129, 2018. DOI: 10.36560/1152018668

CASTOLDI, L., MORALES, R.L., ALBIERO, L.R., NERY, E.F., KELLY, T.O., DALAZEN, J.C., VALLADÃO, D.M.S., ANDRIGHETTI, C.R. In vitro cytotoxicity of Duguetia sp extracts on Ehrlich tumor cells. Scientific Electronic Archives. Vol. 13, p 58-65, 2020. b. DOI: 10.36560/13220201014

CAVALHEIRO, L., GUARIM-NETO, G. Ethnobotany and regional knowledge: combining popular knowledge with the biotechnological potential of plants in the Aldeia Velha community, Chapada dos Guimarães, Mato Grosso, Brazil, Bol. Latinonam. Caribe plantas med. Aromát. Vol. 17, p 197-216, 2018. https://pesquisa.bvsalud.org/portal/resource/pt/biblio-915307

CHE, C.T., ZHANG, H. Plant natural products for human health. International Journal of Molecular Sciences. Vol. 20, p 1 – 4, 2019. DOI: 10.3390/ijms20040830

CHOPRA, B., DHINGRA, A.K. Natural products: a lead for drug discovery and development. Phytotherapy Research. Vol 35, p 4660-4702, 2021. DOI: 10.1002/ptr.7099

COLPAS, F.T., SCHWN-ESTRADA, K.R.F., STANGARLIN, J.R., FERRARESE, M.D.L., SCAPIM, C.A., BONALDO, S.M. Induction of plant defense responses by Ocimum gratissimum L. (Lamiaceae) leaf extracts. Summa Phytopathologica. Vol. 35, p 191-195, 2009. DOI: 10.1590/S0100-54052009000300005

COMIRAN, P.K., RIBEIRO, M.C., SILVA, J.H.G., MATINS, K.O., SANTOS, I.A., CHIARADIA, A.E.F., SILVA, A.Z., DEKKER, R.F.H., BARBOSA-DEKKER, A.M., ALEGRANCI, P., QUEIROZ, E.A.I.F. Botryosphaeran attenuates tumor development and the cancer cachexia syndrome in Walker-256 tumor-bearing obese rats and improves the metabolic and hematological profiles of these rats. Nutrition and Cancer. Vol. 73, p 1175-1192, 2021. DOI: 10.1080/01635581.2020.1789681

CUNHA, A.P.S., BALDISSERA, L., PEREIRA, D.L., ALBIERO, L.R., CASTOLDI, L., SINHORIN, A.P., SINHORIN, V.D.G. Evaluation of the antioxidant potential od Copaifera multijuga in Ehrlich tumor-bearing mice. Acta Amazonica. Vol. 49, p 41-47, 2019. DOI: 10.1590/1809-4392201800672

CUNHA, C.D.A., MUELLER, A. The effect of mate aqueous solution (Ilex paraguariensis) on weight gain of rats. SaBios: Revista Saúde e Biologia.Vol. 9, p 1-5, 2014. https://revista2.grupointegrado.br/revista/index.php/sabios/article/view/881

DENG, L.J., QI, M., LI, N., LEI, Y.H., ZHANG, D.M., CHEN, J.X. Natural products and their derivatives: promising modulators of tumor immunotherapy. Journal of Leukocyte biology. Vol. 108, p 493-508, 2019. DOI: 10.1002/JLB.3MR0320-444R

DENTZ, K.E.V., SILVA, B.S., QUEIROZ, E.A.I.F., BOMFIM, G.F., NASCIMENTO, A.F., SUGIZAKI, M.M., LUVIZOTTO, R.A.M. Hibicus sabdariffa ethanolic extract modulates adipokine levels, decreases visceral fat and improves glycemic profile in high-fat/sugar diet-induced obese rats. Nutrition e Food Science. Vol. 51, 12 pages, 2021. DOI: 10.1108/NFS-03-2020-0092

FARIA, W.C.S., GIORDANI, M.A., ARCAS, A.S., CAVENAGHI, D.F.L.C, OLIVEIRA, A.P., SANTOS, J.F., BARROS, W.M. Novel soybean-based high protein bar rich in isoflavones improves insulin sensitivity in diabetic wistar rats. Journal of Food Science Technology. Vol. 55, p 21-32, 2018. DOI: 10.1007/s13197-017-2753-y

FERRARI, E., VALIATI, S., SHIOMI, H.F. Effect of biofertilizers in the biocontrol of Penicillium sp. In orange pear. Scientific Electronic Archives. Vol. 1, p 1-5, 2012. DOI: 10.36560/1120123

FERREIRA, C.M., ANTONIASSI, N.A.B., SILVA, F.G., POVH, J.A., POTENÇA, A., MORAES, T.C.H., SILVA, T.K.S.T., ABREU, J.A. Histomorphometric characteristics gut of tambaqui after using probiotic on diet and during transport. Pesquisa Veterinária Brasileira. Vol. 34, p 1258-1264, 2014. DOI: 10.1590/S0100-736X2014001200020

FERREIRA, D.T.O., TERÇAS-TRETTEL, A.C.P. Recent dengue vírus infection: epidemiological survey on risk factors associated with infection in a medium-sized city in Mato Grosso. São Paulo Medical Journal. Vol. 140, p 1-9, 2022. DOI: 10.1590/1516-3180.2020.0718.R1.18052021

FERREIRA, J.B., MARTINS, B.H.B., TOMINAGA, W.M., LISBOA, E.M.J., ALBIERO, L.R., ROSA, A.C., SUGUI, M.M. Activity assessment antimutagenic/mutagenic pomegranate (Punica granatum L.) through the in vivo test micronucleous. Scientific Electronic Archives. Vol. 10, p 76-82, 2017. DOI: 10.36560/1032017325

FERREIRA, P.M.P., LIMA, D.J.B., DEBIASI, B.W., SOARES, B.M., MACHADO, K.C., NORONHA, J.C., RODRIGUES, D.J., SINHORIN, A.P., PESSOA, C., JÚNIOR, G.M.V. Antiproliferative activity of Rhinella marina and Rhaebo guttatus venom extract from Southern Amazon. Toxicon. Vol. 72, p 43-51, 2013. DOI: 10.1016/j.toxicon.2013.06.009

FIGUEIREDO, F.F., FILHO, V.C., DAMAZO, A.S., ARUNACHALAM, K., COLODEL, E.M., RIBEIRO, M., VENTURINI, C.L., OLIVEIRA, D.M., MACHADO, M.T.M., PAVAN, E., PAES, R.L., TENFEN, A., ALMEIDA, P.O.A., SIEBERT, D.A., VITALI, L., MACHO, A., MARTINS, D.T.O. Sorocea guilleminiana Gaudich: Wound healing activity, action mehanisms, and chemical characterization of the leaf infusion. Journal of Ethnopharmacology. Vol. 248, p 112307, 2020. DOI: 10.1016/j.jep.2019.112307

FIORI, K.P., TORRES, M.P.R., SCHONS, J.I., RIBEIRO, E.B., NOGUEIRA, R.M., VASCONCELOS, L.G., ANDRIGHETTI, C.R., JACINTO, M.J., VALLADÃO, D.M.S. Microemulsion of Brazil nut oil as a natural product to improve superoxide release in human phagocytes. Química Nova. Vol. 40, p 1051-1057, 2017. DOI: 10.21577/0100-4042.20170113

FONSECA, W.L., ALMEIDA, F.A., LEITE, M.L.T., RAMBO, A.P.P., PETTER, F.A., OLIVEIRA, A.M., CARVALHO, R.M., NETO, F.A., PEREIRA, F.F., JÚNIOR, A.F.M. Bioactivity of aqueous extracts of Anadenanthera macrocarpa to Meloidogyne incognita in cotton crop. Australian Journal of Crop Science. Vol. 11, p 156-161, 2017. DOI: 10.21475/ajcs.17.11.02.p203

FRANÇA, E.L., RIBEIRO, E.B., SCHERER, E.F., CANTARINI, D.G., PESSÔA, R.S., FRANÇA, F.L., HONORIO-FRANÇA, A.C. Effects of Momordica charantia L. on the blood rheological properties in diabetic patients. BioMed Research International. Vol. 2014, 8 pages, 2014. DOI: 10.1155/2014/840379

FRANCO, P.M., OLIVEIRA, M.R.C., ASSIS, J.R., JUNIOR, J.G., TORRES, R.N.S., ALESSI, K.C., SINHORIN, A.P., KERKHOFF, J., OLIVEIRA, A.S. Castor bean extract as a manipulator of ruminal fermentation. Nativa. Vol. 8, p 289-294, 2020. DOI: 10.31413/nativa.v8i2.8325

FURTADO, K.S., POLLETINI, J., DIAS, M.C., RODRIGUES, M.A.M., BARBISAN, L.F. Prevention of rat liver fibrosis and carcinogenesis by coffee and caffeine. Food and Chemical Toxicology. Vol. 64, p 20-26, 2014. DOI: 10.1016/j.fct.2013.11.011

GARCIA, I.J.P., OLIVEIRA, G.C., VALADARES, J.M.M., BANFI, F.F., ANDRADE, S.N., FREITAS, T.R., FILHO, E.S.M., SANTOS, H.L., JÚNIOR, G.M.V., CHAVES, M.H., RODRIGUES, D.J., SANCHEZ, B.A.M., VAROTTI, F.P., BARBOSA, L.A. New bufadienolides extract from Rhinella marina inhibit Na,K-ATPase and induce apoptosis by activating caspases 3 and 9 in human breast and ovarian cancer cells. Steroids. Vol. 152, p 108490, 2019. DOI: 10.1016/j.steroids.2019.108490

GERALDELLI, D., RIBEIRO, M.C., MEDEIROS, T.C., COMIRAN, P.K., MARTINS, K.O., OLIVEIRA, M.F., OLIVEIRA, G.A., DEKKER, R.F.H., BARBOSA-DEKKER, A.M., ALEGRANCI, P., QUEIROZ, E.A.I.F. Tumor development in rats and cancer cachexia are reduced by treatment with botryosphaeran by increasing apoptosis and improving the metabolic profile. Life Sciences. Vol. 252, p. 117608, 2020. DOI: 10.1016/j.lfs.2020.117608

GERALDELLI, D., RIBEIRO, M.C., MEDEIROS, T.C., COMIRAN, P.K., MARTINS, K.O., OLIVEIRA, M.F., OLIVEIRA, G.A., DEKKER, R.F.H., BARBOSA-DEKKER, A.M., ALEGRANCI, P., QUEIROZ, E.A.I.F. Botryosphaeran, a (1→3) (1→6)-b-D-glucan, reduces tumor development and cachexia syndrome in obese male rats by increasing insulin sensitivity and FOXO3a activity. The International Journal of Biological Macromolecules. Vol. 165, p 985-994, 2020. a. DOI: 10.1016/j.ijbiomac.2020.09.168

GERON, L.J.V., VELOSO, L.E.C., MORAES, E.H.B.K., MORAES, K.A.K., GOMES, H.F.B., ZANIN, S.F.P., CARVALHO, G.M., BRITO, T.R., SILVA, P.S., ALMEIDA, T.A. Phytogenic additive noni (Morinda citrifolia) in feed of confined lambs. Semina: Ciências Agrárias. Vol. 40, p 3679-3690,

2019. DOI: 10.5433/1679-0359.2019v40n6Supl3p3679

GHELLER, A.C.G.V., KERKOFF, J., JÚNIOR, G.M.V., CAMPOS, K.E., SUGUI, M.M. Antimutagenic effect of Hibiscus sabdariffa L. aqueous extract on rats treated with monosodium glutamate. The Scientific World Journal.Vol. 2017, 8 pages, 2017. DOI: 10.1155/2017/9392532

GIORDANI, M.A., COLLICCHIO, T.C.M, ASCÊNCIO, S.D., MARTINS, D.T.O., BALOGUN, S.O., BIESKI, I.G.C., SILVA, L.A., COLODEL, E.M., SOUZA, R.L., SOUZA, D.L.P., FRANÇA, S.A., ANDRADE, C.M.B., KAWASHITA, N.H. Hydroethanolic extract of the inner stem bark of Cedrela odorata has low toxicity and reduces hyperglycemia induced by an overload of sucrose and glucose. Journal of Ethnopharmacology. Vol. 162, p 352-361, 2015. DOI: 10.1016/j.jep.2014.12.059

GODOY, B.S.A., SINHORIN, V.D.G., CASTOLDI, L., SUGUI, M.M., BICUDO, R.C., SINHORIN, A.P. First phytochemical study and biological activity of the leaves ethanolic extract from Cissus spinosa Cambess. Scientia Medica. Vol. 30, p 1-17, 2020. DOI: 10.15448/1980-6108.2020.1.34860

GOIS, F.D., SBARDELLA, M., LIMA, C.B., MIGOTTO, D.L., CAIRO, P.L.G., GARBOSSA, C.A.P., RACANICCI, A.M.C., COSTA, L.B. Dietary Brazilian red pepper essential oil on pork meat quality and lipid oxidation. Ciência Rural. Vol. 47, 7 pages, 2017. DOI: 10.1590/0103-8478cr20160127

GOMES, R.M., PAULO, L.F., PANIZZON, C.P.N.B., NEVES, C.Q., CORDEIRO, B.C., ZANONI, J.N., FRANCISCO, F.A., PIOVAN, S., MATHIAS, P.C.F., LONGHINI, R., MELLO, J.C.P., OLIVEIRA, J.C., PEDRINO, G.R., REIS, A.A.S., CECCHINI, A.L., NATALI, M.R.M. Anti-diabetic Effects of the ethyl-acetate fraction of Trichilia catigua in streptozotocin-induced type 1 diabetic rats. Cellular Physiology and Biochemistry. Vol. 42, p1087-1097, 2017. DOI: 10.1159/000478761

GONÇALVES, P.J.R.O., OLIVEIRA, A.G., FREITAS, V.F., CHIARI, N.A., NAVARRO, M.P., CELY, M.T., LEAL, A.C., ANDRADE, G. Plant growth-promoting microbial inoculant for Schizolobium parahyba pv. parahyba. Revista Árvore. Vol. 39, p 663-670, 2015. DOI: 10.1590/0100-67622015000400008

GREGOLIN, F.S., BONALDO, S.M., SINHORIN, A.P., BANDERÓ, J.L., WOBETO, C. The in vitro control of Fusarium proliferatum by propolis ethanolic extracts. Revista de Ciências Agrárias. Vol. 42, p 456-463, 2019. DOI: 10.19084/rca.17471

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (BRASIL). Amazônia Legal. Brasília, 10 de agosto de 2022. https://www.ibge.gov.br/geociencias/cartas-e-mapas/mapas-regionais/15819-amazonia-legal.html?=&t=o-que-e

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (Brasil). Mato Grosso: história e fotos. Brasília, 10 de agosto de 2022. https://cidades.ibge.gov.br/brasil/mt/historico

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (BRASIL). Mato Grosso: Sinop. Brasília, 10 de agosto de 2022. https://cidades.ibge.gov.br/brasil/mt/sinop/panorama

JAQUES, J.A.S., DOLESKI, P.H., CASTILHOS, L.G., ROSA, M.M., SOUZA, V.C.G., CARVALHO, F.B., MARISCO, P., THORSTENBERG, M.L.P., REZER, J.F.P., RUCHEL, J.B., CORADINI, K., BECK, R.C.R., RUBIN, M.A., SCHETINGER, M.R.C., LEAL, D.B.R. Free and nanoencapsulated curcumin prevents cigarette smoke-induced cognitive impairment and redox imbalance. Neurobiology of Learning and Memory. Vol. 100, p 98-107, 2013. DOI: 10.1016/j.nlm.2012.12.007

JIANG, Y., OGUNADE, I.M., KIM, D.H., LI, X., PECH-CERVANTES, A.A., ARRIOLA, K.G., OLIVEIRA, A.S., DRIVER, J.P., FERRARETTO, L.F., STAPLES, C.R., VYAS, D., ADESOGAN, A.T. Effect of adding clay with or without a Saccharomyces cerevisiae fermentation product on the health and performance of lactating dairy cows challenged with dietary aflatoxin B1. Journal of Dairy Science. Vol. 101, p 3008-3019, 2018. DOI: https://doi.org/10.3168/jds.2017-13678

KATZ, L., BALTZ, R.H. Natural products discovery: past, present, and future. Journal ind Microbiology and Biotechnology. Vol. 43, p 155 – 176, 2016. DOI: 10.1007/s10295-015-1723-5

KHOSHRU, B., MITRA, D., KHOSHMANZAR, E., MYO, E.M., UNIYAL, N., MAHAKUR, B., MOHAPATRA, P.K., PANNEERSELVAM, P., BOUTAJ, H., ALIZADEH, M., CELY, M.V.T., SENAPATI, A., RANI, A. Current scenario and future prospects of plant growth-promoting rhizobacteria: an economic valuable resource for the agriculture revival under stressful conditions. Journal of Plant Nutrition. Vol. 43, 20 pages, 2020. DOI: 10.1080/01904167.2020.1799004

LEGUIZAMÓN, N.P., RODRIGUES, E.M., CAMPOS, M.L., NOGUEIRA, A.V.B., VIOLA, K.S., SCHNEIDER, V.K., NEO-JUSTINO, D.M., TANOMARU-FILHO, M., ZAMBUZZI, W.F., HENRIQUE-SILVA, F., SOARES-COSTA, A., FARIA, G., CIRELLI, J.A. In vivo and in vitro anti-inflammatory and pro-osteogenic effects of citrus cystatin (CsinCPI-2). Cytokine. Vol. 123, p 154760, 2019. DOI: 10.1016/j.cyto.2019.154760

LESSNA, E., BRUNING, L.F., BOLINA, C.S., LIMA, D.S., WATANABE, I., CIENA, A.P. Possible effects of the Agaricus brasiliensis extract on the cardiac morphology in mice. Journal of Morphological Science. Vol. 32, p 16-21, 2015. DOI: 10.4322/jms.069114

LIMA, A., RIBEIRO, A.S., BONALDO, S.M. Effect of essential oils of Syzygium aromaticum and Melaleuca alternifolia on isolates of Aspergillus sp. Scientific Electronic Archives. Vol. 5, p 63-67, 2014. DOI: 10.36560/50201453

LIMA, P.L.A., RIBEIRO, D.A., SUGUI, M.M., TEREZAN, A.P., DOMINGUES, M.A.C., FILHO, E.R., AZEVEDO, L., SALVADORI, D.M.F., RIBEIRO, L.R. Storage results in loss of the antigenotoxic properties of Lentinula edodes (shiitake mushroom) and development of in vivo genotoxicity. Journal of Food Biochemistry. Vol. 34, p 206-228, 2010. DOI: 10.1111/j.1745-4514.2009.00275.x

LIMA, P.L.A., SUGUI, M.M., PETRÍCIO, A.I.M., VILELA, L.C., PINTO, A.V.F., MARTINS, P.R., KANENO, R., RIBEIRO, D.A., SALVADORI, D.M.F., RIBEIRO, L.R. Lentinula edodes (shiitake) modulates chemically induced mutagenesis by enhancing pitting. Journal of Medicinal Food. Vol. 16, p 733-739, 2013. DOI: 10.1089/jmf.2013.0015

LORINI, A., BONALDO, S.M., MENDES, B.L. Volatile effect of essential oils on the growth of pathogens in almonds of Brazil nuts. Scientia Agraria Paranaensis. Vol. 15, p 121-126, 2016. DOI: 10.18188/1983-1471/sap.v15n2p121-126

LORINI, A., WOBETO, C., BONALDO, S.M., BOTELHO, S.C.C., SINHORIN, A.P. Chemical composition and antifungal activity of propolis on Aspergillus flavus. Bioscience Journal. Vol. 34, p 1298-1307, 2018. DOI: 10.14393/BJ-v34n5a2018-36601

LUCINI, T., SCABENI, C., DEDORDI, C., HIROSE, E., SHIOMI, H.F. Effect of aqueous extract of Capsicum baccatum on mortality and oviposition of Tetranychus ludeni (Acari: Tetranychidae). Scientia Agraria. Vol. 11, p 355-358, 2010. https://www.redalyc.org/pdf/995/99515213011.pdf

LUIZ, T.C., CUNHA, A.P.S., AGUIAR, D.H., SUGUI, M.M., BICUDO, R.C., SINHORIN, A.P., SINHORIN, V.D.G. Antioxidant potencial of Carica papaya Linn (Caricaceae) çeaf extract in mice with cyclophosphamide induced oxidative stress. Scientia Medica. Vol. 30, p 1-15, 2020. DOI: 10.15448/1980-6108.2020.1.34702

LUIZ, T.C., RIALTO, L.F., MOURA, F.R., AGUIAR, D.H., SUGUI, M.M., BICUDO, R.C., SINHORIN, A.P., SINHORIN, V.D.G. Chemoprtective effect of leaf extracts of Cecropia distachya Huber (Urticaceae) in mice submitted to oxidative stress induced by cyclophosphamide. Fronteiras: Journal of Social, Technological and Environmental Science. Vol. 9, p 103-127, 2020. a. DOI: 10.21664/2238-8869.2020v9i2.p103-127

LUVIZOTTO, R.A.M., NASCIMENTO, A.F., IMAIZUMI, E., PIERINE, D.T., CONDE, S.J., CORREA, C.R., YEUM, K.J., FERREIRA, A.L.A. Lycopene supplementation modulates plasma concentrations and epididymal adipose tissue mRNA of leptin, resistin and IL-6 in diet-induced obese rats. British Journal of Nutrition. Vol. 110, p 1803-1809, 2013. DOI: 10.1017/S0007114513001256

LUVIZOTTO, R.A.M., NASCIMENTO, A.F., MIRANDA, N.C.M, WANG, X.D., FERREIRA, A.L.A. Lycopene-rich tomato oleoresin modulates plasma adiponectin concentration and mRNA levels of adiponectin, SIRT1, and FoxO1 in adipose tissue of obese rats. Human and Experimental Toxicology. Vol. 34, p 612-619, 2015. DOI: 10.1177/0960327114551395

MAURO, M., GRANDIS, R.A., CAMPOS, M.L., BAUERMEISTER, A., PECCININI, R.G., PAVAN, F.R., LOPES, N.P., MORAES, N.V. Acid diterpenes from Copaiba oleoresin (Copaifera langsdorffii): Chemical and plasma stability and intestinal permeability using Caco-2 cells. Journal of Ethnopharmacology. Vol. 235, p 183-189, 2019. DOI: 10.1016/j.jep.2019.02.017

MACHADO, K.C., SOUSA, L.Q., LIMA, D.J.B., SOARES, B.M., CAVALCANTI, B.C., MARANHÃO, S.S., NORONHA, J.C., RODRIGUES, D.J., MILITÃO, G.C.G., CHAVES, M.H., VIEIRA-JÚNIOR, G.M., PESSOA, C., MORAES, M.O., SOUSA, J.M.C., MELO-CAVALCANTE, A.M.C., FERREIRA, P.M.P. Marinobufagin, a molecule from poisonous frogs, causes biochemical, morphological and cell cycle changes in human neoplasms and vegetal cells. Toxicology Letters. Vol. 285, p 121-131, 2018. DOI: 10.1016/j.toxlet.2017.12.018

MACHADO, N.J.B., CRUZ, F.G.G., BRASIL, R.J.M., RUFINO, J.P.F., FREITAS, L.W., DILELIS, F., QUARESMA, D.V., LIMA, C.A.R. Effects of xylanase and probiotic supplementation on broiler chicken diets. Revista Brasileira de Zootecnia. Vol. 49, p e20190216, 2020. DOI: 10.37496/rbz4920190216

MACHADO, R.F.C., ANDRADE, E.A., WOBETO, C., BONALDO, S.M. Essential oils in quality and decay control postharvest in tomato. Revista de Ciências Agroambientais. Vol. 15, p 32-42, 2017.

MAGALHÃES, L.M., SINHORIN, V.D.G., SOUZA, C.C.P., BICUDO, R.C., SINHORIN, A.P. Antioxidant activity and flavonoids identification by LC-MS/MS analysis in leaf extracts from Trattinnickia rhoifolia Willd. Fronteiras: Journal of Social, Technological and Environmental Science. Vol. 8, p 13-34, 2019. DOI: 10.21664/2238-8869.2019v8i2.p13-34

MARTINS, B.H.B., TOMINAGA, W.M., CASTOLDI, L., CAMARGO, E.A., PEREIRA, D.L., LISBOA, E.M.J., ALBIERO, L.R., FERREIRA, J.B., MELCHIROS, N., SUGUI, M.M. Evaluation of the antimutagenic and cytotoxic activity of Morinda citrifolia Linn. (noni). Scientific Electronic Archives. Vol. 12, p 124-129, 2019. DOI: 10.36560/1212019631

MARTINS, P.R., GAMEIRO, M.C., CASTOLDI, L., ROMAGNOLI, G.G., LOPES, F.C., PINTO, A.V.F.S., LOYOLA, W., KANENO, R. Polysaccharide-rich fraction of Agaricus brasiliensis enhances the candidacidal activity of murine macrophages. Memórias do Instituto Oswaldo Cruz. Vol. 103, p 244-250, 2008. DOI: 10.1590/S0074-02762008005000011

MATIELLO, J., BONALDO, S.M. Eliciting activity of phytoalexins in soybean and sorghum by extracts and tinctures of medicinal species. Revista Brasileira de Plantas Medicinais. Vol. 15, p 541-550, 2013. DOI: 10.1590/S1516-05722013000400010.

MATIELLO, J., RAASCH-FERNANDES, L.D., BERBER, G.C.M., TRENTO, R.A., BONALDO, S.M. Synthesis of phytoalexins in soybean and soghum for extracts and tinctures belong to three forest species, Revista em Agronegócio e Meio Ambiente. Vol. 9, p 617-633, 2016. DOI: 10.17765/2176-9168.2016v9n3p617-633

MELENDEZ-MARTINEZ, A.J., NASCIMENTO, A.F., WANG, Y., LIU, C., MAO, Y., WANG, X.D. Effect of tomato extract supplementation against high-fat diet-induced hepatic lesions. Hepatobiliary Surgery and Nutrition. Vol. 2, p 198-208. 2013. DOI: 10.3978/j.issn.2304-3881.2013.07.04

MELO, A.M.M.F., MACORINI, L.F.B., MUELLER, A., CARDOSO, C.A.L., GAMA, S., GOMES, S.M., SILVEIRA, S. Anxiogenic effects of Tabernaemontana solanifolia A. DC. (Apocynaceae) extracts in rats tested in the elevated plus-maze. Revista Cubana de Plantas Medicinales. Vol. 18, p 216-223, 2013. https://repositorio.unb.br/handle/10482/13068?locale=en

MENDES, B.L., ZANATTO, I.B., RIBEIRO, A.S., PASTORELLO, M., BONALDO, S.M. Influence of the oil pequi in the growth mycelial and sporulation of Colletotrichum musae and growth micelial of Rhizopus sp. in vitro. Scientific Electronic Archives. Vol. 3, p 20-23, 2013. DOI: 10.36560/30201336

MENESES, D.M., MORAES, E.H.B.K., BATISTA, E.D., OLIVEIRA, A.S., SILVA, S.R., STINGUEL, H., ROCHA, P.R., ORTELAM, J.C., SANTOS, K.R., SOCREPPA, L.M., MORAES, K.A.K. Dried whole cupuassu (Theobroma grandiflorum) nuts as an alternative energy feedstuff for beef cattle grazing tropical pasture. Animal Production Science. Vol. 60, p 1614-1619, 2020. DOI: 10.1071/AN18668

MODESTO, V.C., EVANGELISTA, F.M., SOARES, M.R., ALVES, M.R., NEVES, M.A.B., CORRÊA, M.L.M., SOUSA, N.F.S., GALVÃO, N.D., ANDRADE, A.C.S. Cancer mortality in the State of Mato Grosso from 2000 to 2015: temporal trend and regional differences. Revista Brasileira de Epidemiologia. Vol. 25, p 1-13, 2022. DOI: 10.1590/1980-549720220005.supl.1.1

MONTESCHIO, J.O., VARGAS-JUNIOR, F.M., ALMEIDA, F.L.A., PINTO, L.A.M., KANEKO, I.N., ALMEIDA, A.A., FREITAS, L.W., ALVES, S.P.A., BESSA, R.J.B., PRADO, I.N. The effects of encapsulated active principles (eugenol, thymol and vanillin) and clove and rosemary essential oils on the structure, collagen content, chemical composition and fatty acid profile of Nellore heifers muscle. Meat Science. Vol. 155, p 27-35, 2019. DOI: 10.1016/j.meatsci.2019.04.019

MORAES, M.E.A., BEZERRA, M.M., BEZERRA, F.A.F., MORAES, R.A., CAVALCANTI, P.P., UCHOA, C.R.A., LIMA, F.A.V., MORAES, M.O. Safety evaluation of Elixir paregorico® in healthy volunteers: a phase I study. Human & Experimental Toxicology. Vol. 27, p 751-756, 2008. DOI: 10.1177/0960327108090274

MORAES, M.E.A., CUNHA, G.H., BEZERRA, M.M., FECHINE, F.V., PONTES, A.V., ANDRADE, W.S., BEZERRA, F.A.F., MORAES, M.O., CAVALCANTI, P.P. Efficacy of the Mentha crispa in the treatment of women with Trichomonas vaginalis infection. Archives of Gynecology Obstet. Vol. 286, p 125-130, 2012. DOI: 10.1007/s00404-012-2251-4

MOREIRA, C.G.A., SCHWAN-ESTRADA, K.R.F., BONALDO, S.M., STANGARLIN, J.R., CRUZ, M.E.S. Partial characterization of fractions from extracts of Cymbopogon nardus with elicitor activity of phytoalexins in sorghum and soy and effect on Colletotrichum lagenarium. Summa Phytopathologica. Vol. 34, p 332-337, 2008. https://www.scielo.br/j/sp/a/pPVCrd3TczQM6hvWHYFQ5QR/?lang=pt&format=pdf

MURATE, L.S., OLIVEIRA, A.G., HIGASHI, A.Y., BARAZETTI, A.R., SIMINIONATO, A.S., SILVA, C.S., SIMÕES, G.C., SANTOS, I.M.O., FERREIRA, M.R., CELY, M.V.T., NAVARRO, M.O.P., FREITAS, V.F., NOGUEIRA, M.A., MELLO, J.C.P., JÚNIOR, R.P.L., ANDRADE, G. Activity of secondary bacterial metabolites in the control of citrus canker. Agricultural Sciences. Vol. 6, p 295-303, 2015. DOI: 10.4236/as.2015.63030

OLIVEIRA, A.F., CASTOLDI, L., JÚNIOR, G.M.V., FILHO, E.S.M., CHAVES, M.H., RODRIGUES, D.J., SUGUI, M.M. Evaluation of antimutagenic and cytotoxic activity of skin secretion extract of Rhinella marina e Rhaebo guttatus (Anura, Bufonidae). Acta Amazonica. Vol. 49, p 145-151, 2019. a. DOI: 10.1590/1809-4392201801751

OLIVEIRA, A.G., SPAGO, F.R., SIMIONATO, A.S., NAVARRO, M.O.P., SILVA, C.S., BARAZETTI, A.R., CELY, M.V.T., TISCHER, C.A., SAN MARTIN, J.A.B., ANDRADE, C.G.T.J., NOVELLO, C.R., MELLO, J.C.P., ANDRADE, G. Bioactive organocopper compound from Pseudomonas aeruginosa inhibits the growth of Xanthomonas citri subsp. Citri. Frontiers in Microbiology. Vol. 7, p article 113, 2016. DOI: 10.3389/fmicb.2016.00113

OLIVEIRA, A.S., OLIVEIRA, M.R.C., CAMPOS, J.M.S., LANA, R.P., MACHADO, O.L.T., RETAMAL, C.A., DETMANN, E., VALADARES FILHO, S.C. In vitro ruminal degradation of ricin and its effect on microbial growth. Animal Feed Science and Technology. Vol. 157, p 41-54, 2010. DOI: 10.1016/j.anifeedsci.2010.01.006

OLIVEIRA, S.A.B., BARBOSA, F.R., ANDRADE, E.A., FERRANI, S.R., BONALDO, S.M. Volatile compounds of saprobic conidial fungi from Southern Amazonia for in vitro control of phytopathogens. Summa Phytophathologica. Vol. 45, p 302-307, 2019. DOI: 10.1590/0100-5405/178478

PARACATU, L.C., BONACORSI, C., FARIAS, C.M.Q.G., NAZARÉ, A.C., PETRÔNIO, M.S., REGASINI, L.O., SILVA, D.H.S., RADDI, M.S.G., FONSECA, L.M., XIMENES, V.F. Alkyl caffeates as anti-Helicobacter pylori and scavenger of oxidants produced by neutrophils. Medicinal Chemistry. Vol. 10, p 74-80, 2014. DOI: 10.2174/157340641001131226125042.

PEREIRA, C.S., REMPEL, D., SINHORIN, A.P., FERNANDES, H., FIORINI, I.V.A. Application of ethanolic propolis extract in soybean diseases. Revista de Ciências Agrárias. Vol. 40, p 854-862, 2017. DOI: 10.19084/RCA17029

PEREIRA, D.L., CUNHA, A.P.S., CARDOSO, C.R.P., ROCHA, C.Q., VILEGAS, W., SINHORIN, A.P., SINHORIN, V.D.G. Antioxidant and hepatoprotective effects of ethanolic and ethyl acetate stem bark extracts of Copaifera multijuga (Fabaceae) in mice. Acta Amazonica. Vol. 48, p 347-357, 2018. DOI: 10.1590/1809-4392201704473

PIERINE, D.T., NAVARRO, M.E.L., MINATEL, I.O., LUVIZOTTO, R.A.M., NASCIMENTO, A.F., FERREIRA, A.L.A., YEUM, K.J., CORRÊA, C.R. Lycopne supplementation reduces TNF-a via RAGE in the kidney of obese rats. Nutrition & Diabetes. Vol. 4, p 1-6, 214. DOI: 10.1177/0960327114551395

PIRES, J., CARGNIN, S.T., COSTA, S.A., SINHORIN, V.D.G., DAMAZO, A.S., A.P. SINHORIN, A.P., BICUDO, R.C., CAVALHEIRO, L., VALLADÃO, D.M.S., POHLMANN, A.R., GUTERRES, S.S., FERRARINI, S.R. Healing of dermal wounds property of Caryocar Brasiliense oil loades polymeric lipid-core nanocapsules: formulation and in vivo evaluation. European Journal of Pharmaceutical Sciences. Vol. 150, p 105356, 2020. a. DOI: 10.1016/j.ejps.2020.105356

PIRES, J., CONCEIÇÃO, A.G.B., COSTA, S.A., SILVA, K.P., FERRARINI, S.R., ANDRADE, C.M.B. Evaluation of cytotoxicity of polymeric lipid-core nanocapsules containing pequi oil (Caryocar Brasiliense Cambess) as a structuring agent. Revista Panorâmica. Vol. 2, p 21-38, 2020. file:///Users/lindseycastoldi/Downloads/administrador,+AVALIA%C3%87%C3%83O+DA+CITOTOXICIDADE%20(1).pdf

QUEIROZ, E.A.I.F., FORTES, Z.B., CUNHA, M.A.A., BARBOSA, A.M., KHAPER, N., DEKKER, R.F.H. Antiproliferative and pro-apoptotic effects of three fungal exocellular b-glucan in MCF-7 breast cancer cell is mediated by oxidative stress, AMP-activated protein kinase (AMPK) and Forkhead transcription factor, FOXO3a. The International Journal of Biochemistry & Cell Biology. Vol. 67, p 14-24, 2015. a. DOI: 10.1016/j.biocel.2015.08.003

QUEIROZ, E.A.I.F., FORTES, Z.B., CUNHA, M.A.A., SARILMISER, H.K., DEKKER, A.M.B., ÖNER, E.T., DEKKER, R.F.H., KHAPER, N. Levan promotes antiproliferative and pro-apoptotic effects in MCF-7 breast cancer cells mediated by oxidative stress. International Journal of Biological Macromolecules. Vol. 102, p 565-570, 2017. DOI: 10.1016/j.ijbiomac.2017.04.035

QUEIROZ, G.M., POLITI, F.A.S., RODRIGUES, E.R., SOUZA-MOREIRA, T.M., MOREIRA, R.R.D., CARDOSO, C.R.P., SANTOS, L.C., PIETRO, R.C.L.R. Phytochemical characterization, antimicrobial activity, and antioxidant potencial of Equisetum hyemale L. (Equisetaceae) extracts. Journal of Medicinal Food. Vol. 18, p 830-834, 2015. DOI: 10.1089/jmf.2014.0089

RAASCH-FERNANDES, L.D., BONALDO, S.M., RODRIGUES, D.J., VIEIRA-JÚNIOR, G.M., SCHWAN-ESTRADA, K.R.F., SILVA, C.R., VERÇOSA, A.G.A., OLIVEIRA, D.L., DEBIASI, BW. Induction of phytoalexins and proteins related to pathogenesis in plants treated with extracts of cutaneous secretions of southern Amazonian Bufonidae amphibians. PLoS ONE. Vol. 14, p e0211020, 2019. DOI: 10.1371/journal.pone.0211020

RAMSEY, J.T., SHROPSHIRE, B.C., NAGY, T.R., CHAMBERS, K.D., LI, Y., KORACH, K.S. Essential oils and health. Yale Journal of Biology and Medicine. Vol. 93, p 291-305, 2020.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7309671/

RODRIGUES, P.F.G., ALBIERO, L.R., NERY, E.F., KELLY, T.O., DALAZEN, J.C.S., PEREIRA, D.L., SINHORIN, A.P., SINHORIN, V.D.G., CASTOLDI, L. Natural killer activity of the spleen cells of Ehrlich tumor-bearing mice treated with Copaifera multijuga extract. Scientia Medica. Vol. 29, p e32408, 2019. DOI: 10.15448/1980-6108.2019.1.32408

SANTOS, B.T., BONALDO, S.M., BULHÕES, C.C. Protection of cotton against Colletotrichum gossypii and Colletotrichum gossypii var. cephalosporioides by aqueous extracts of medicinal plants and forest species. Enciclopédia Biosfera. Vol. 7, p 862-871, 2011. https://www.conhecer.org.br/enciclop/2011b/ciencias%20agrarias/protecao.pdf

SANTOS, B.T., BULHÕES, C.C., BONALDO, S.M. Inducing resistence in cotton against Colletotrichum gossypii var. cephalosporioides with essential oils. Scientific Electronic Archives. Vol. 9, p 45-50, 2016. DOI: 10.36560/952016387

SANTOS, J.A., PICCINELLI, A.C., FORMAGIO, M.D., OLIVEIRA, C.S., SANTOS, E.P., STEFANELLO, M.E.A., JÚNIOR, U.L., OLIVEIRA, R.J., SUGIZAKI, M.M., KASSUYA, C.A.L. Antidepressive and antinociceptive effects of ethanolic extract and fruticuline A from Salvia lachnostachys Benth leaveson rodents. PLoS One. Vol. 12, p e0172151, 2017. DOI: 10.1371/journal.pone.0172151

SBARDELLA, M., RACANICCI, A.M.C., GOIS, F.D., LIMA, C.B., MIGOTTO, D.L., COSTA, L.B., MIYADA, V.S. Effects of dietary hop (Humulis lupulus L.) b-acids on quality attributes, composition and oxidative stability of pork meat. Journal of the Science Food Agriculture. Vol. 98, p 2385-2392, 2018. DOI: 10.1002/jsfa.8730

SHIOMI, H.F., FERREIRA, M.V.R., MELO, I.S. Bioprospecting bacterial strains for biological control of white mold on soybean. Scientific Electronic Archives. Vol. 10, p 56-63, 2017. https://sea.ufr.edu.br/SEA/article/view/432/pdf

SHIOMI, H.F., MELO, I.S., MINHONI, M.T.A. Assessing of endophytic bacteria for biological control of northem corn leaf blight (Exserohilum turcicum). Arquivos Instituto Biológico. Vol. 82, p 1-4, 2015. DOI: 10.1590/1808-1657000642013

SILVA, A.Z., COSTA, F.P.L., SOUZA, I.L., RIBEIRO, M.C., GIORDANI, M.A., QUEIROZ, D.A., LUVIZOTTO, R.A.M., NASCIMENTO, A.F., BOMFIM, G.F., SUGIZAKI, M.M., DEKKER, R.F.H., BARBOSA-DEKKER, A.M., QUEIROZ, E.A.I.F. Botryosphaeran reduces obesity, hepatic steatosis, dyslipidaemia, insulin resistance and glucose intolerance in diet-induced obese rats. Life Sciences. Vol. 211, p 147-156, 2018. DOI: 10.1016/j.lfs.2018.09.027

SINHORIN, V.D.G., PATIAS, N.S., MOURA, F.R., CUNHA, A.P.S., LIMA, R.R.S., COSTA, T.B., COSTA, R.J., CAVALHEIRO, L., BICUDO, R.C., SINHORIN, A.P. Identification of flavonoids by LC-MS/MS in leaves extract from Protium heptaphyllum (Aubl.) March and antioxidant activity in mice. The Natural Products Journal. Vol. 10, p 1-10, 2020. DOI: 10.2174/2210315510999200817165311

SOUZA, C.C.P., MAGALHÃES, L.M., COSTA, T.B., BICUDO, R.C., SINHORIN, V.D.G., SINHORIN, A.P. Identification of flavonoids by LC-MS/MS analysis from leaf extracts of Caesalpinia ferrea Mart. and evaluation of the reversal of oxidative stress in mice. Revista Brasileira de Plantas Medicinais. Vol. 19, p 610-618. 2017.

SOUZA, H.A., MORAES, E.H.B.K., OLIVEIRA, A.S., BATISTA, E.D., SANTOS, K.R., SOUSA, J.N., ORTELAN, J.C., LAMAG, A., MORAES, K.A.K. Cashew processing product as alternative energy feedstuff for grazing beef cattle under tropical conditions. Livestock Science. Vol. 236, p 104022, 2020. DOI: 10.1016/j.livsci.2020.104022

SOUZA, J.G., OLINI, L.M.G., ARAUJO, C.V., MENDONÇA, S., ZERVOUDAKIS, J.T., CABRAL, L.S., OGUNADE, I.M., OLIVEIRA, A.S. Performance, hepatic function and efficiency of nutrient utilisation of grazing dairy cows supplemented with alkaline-treated Jatropha curcas L. meal. Animal Production Science. Vol. 58, p 2280-2287, 2017. DOI: 10.1071/AN16717

SOUZA, K.G., TADASHI, M.H., JÚNIOR, G.M.V., SUGUI, M.M. Genotoxic evaluation of sibipiruna extract (Caesalpinia peltophoroides Benth) in vivo. Scientific Electronic Archives. Vol. 12, p 130-137, 2019. DOI: 10.36560/1212019657

TOMAZELI, E.C., VALLADÃO, D.M.S., ANDRIGHETTI, C.R., MAGALHÃES, M., BATIROLLA, L.D., BONACORSI, C. Antimicrobial and antioxidant activity of the leaves and flowers of Tabebuia aurea and Cordia glabrata. Scientific Electronic Archives. Vol. 13, p 59-68, 2020. DOI: 10.36560/1352020918

UNIVERSIDADE FEDERAL DE MATO GROSSO (BRASIL). Conheça mais sobre a UFMT. Cuiabá, 10 agosto de 2022. https://www.ufmt.br/pagina/ufmt/112

VALIATI, S., FERRARI, E., SHIOMI, H.F. Effect of the isolated bacteria in the biocontrol “in vitro” of Aspergillus sp. Scientific Electronic Archives. Vol. 1, p 11-15, 2012. https://sea.ufr.edu.br/SEA/article/view/5/7

VALLI, M., RUSSO, H.M., BOLZANI, V.S. The potencial cntributuion of the natural products from Brazilian biodiversity to bioeconomy. Anais da Academia Brasileira de Ciências. Vol. 90, p 763 – 778, 2018. DOI: 10.1590/S0100-40422009000300012

VENAZZI, C.B., SIQUEIRA, P.H.G.S., ESPINA, P.R.G., PRIMÃO, J.C.M., AGOSTINHO, K.M., ARAÚJO, N.T.C. Evaluation of the process of venous ulcer healing, treated with babosa gel (Aloe barbadensis Miller): um estudo de caso. Scientifc Electronic Archives. Vol. 11, p 84-92, 2018. https://sea.ufr.edu.br/SEA/article/view/572/pdf

WYREPKOWSKI, C.C., COSTA, D.L.M.G., SINHORIN, A.P., VILEGAS, W., GRANDIS, R.A., RESENDE, F.A., VARANDA, E.A., SANTOS, L.C. Characterization and quantification of the compounds of the ethanolic extract from Caesalpinia ferrea stem bark and evaluation of their mutagenic activity. Molecules. Vol. 19, p 16039-16057, 2014. DOI: 10.3390/molecules191016039

ZAMBIAZZI, E.V., CORASSA, J.N., GUILHERME, S.R., BONALDO, S.M. Biological control in-vitro brown stink bug (Euschistus heros) with Beauveria bassiana. Revista Trópica – Ciências Agrárias e Biológicas. Vol. 5, p 43-48, 2011. file:///Users/lindseycastoldi/Downloads/534-3733-1-PB.pdf

ZAMBIAZZI, E.V., GUILHERME, S.R., CORASSA, J.N., BONALDO, S.M., ZUFFO, A.M., SOARES, I.O., OLIVEIRA, D.C.S. Pathogenicity of Beauveria bassiana in in vitro control of the maize cob borer (Helicoverpa zea). Revista de Ciências Agrárias. Vol. 39, p 89-94, 2016. DOI: 10.19084/RCA15002

ZANATTO, I.B., BONALDO, S.M., PEREIRA, C.S. Fungicides and ethanolic extract of propolis in the control of late season soybean diseases. Revista de Ciências Agrárias. Vol. 41, p 165-174, 2018. DOI: 10.19084/RCA17062

ZANCO, P., SOUZA, E.F., BONACORSI, C. Evaluation of antimicrobial and antioxidant activity of leaf teas blackberry (Morus nigra). Scientific Electronic Archives. Vol. 10, p 150-157, 2017. DOI: 10.36560/1012017368

ZUANAZZI, J.A.S., MAYORGA, P. Fitoprodutos e desenvolvimento econômico. Química Nova. Vol. 33, p 1421-1428, 2010. DOI: 10.1590/S0100-40422010000600037