Chapter

Brazilian Amazon Plants: An Overview of Chemical Composition and Biological Activity

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Abstract

Currently, the number of diseases has been increasing and reaching the population directly, and the deliberate use of drugs is creating resistance of pathogens in several drugs, a fact evidenced by the increased ineffectiveness of drugs and the persistence of infections in the body. Given this, it is necessary to search for new alternative drugs that can effectively promote effective therapy. It is possible to highlight, in Brazil, the diversity of the Amazonian flora, which has several species with considerable potential as a source of new molecules with identified biological activity. Thus, a literature review was conducted in order to describe the applications of some Amazonian extracts and their chemical characteristics and biological activity. The Amazon rain forest has considerable diversity of plant species with biological properties that may be useful to public health. Further research is needed to identify new compounds with health benefits.

Keywords: Amazonian extracts, biological activity, chemical composition, alternative treatment

1. Introduction

The Amazon rain forest is known to have an extensive territory, including several Brazilian states and some other American countries, full of a considerable diversity of fauna and flora forming a rich ecosystem. Thus, due to the diversity of plants and the side effects of the drugs currently used, such as the increasing antimicrobial resistance, it is necessary to obtain new alternatives to enable the effective treatment and/or prevention of diseases [1].

Brazilian biodiversity is recognized as one of the most representative of the earth's biosphere and plays an important role in its maintenance and in human health by providing basic products and ecosystem services. In addition, Brazilian

Amazon provides a lot of products including food (such as livestock, fruits, and vegetables), wood, and even drugs [2].

Given this, the aim of this chapter is to conduct a review, presenting some Amazonian species included in Brazilian Amazon biodiversity, as well as the biological activity of their extracts.

2. *Astrocaryum vulgare Mart* (tucumã)

The Amazon has innumerable native species of fruit plants that have economic, technological, and nutritional potential, which has been arousing the interest of scientific studies in many fields, such as food science, pharmaceutical, cosmetic, flavoring, and essences. Allied to these virtues is the tucumã (*Astrocaryum vulgare* Mart.), species belonging to the family of Arecaceae, popularly known by the name of tucumanzeiro. Fruits and seeds are used in human and animal food and leaves and stems in the construction of houses by the people in the interior of the Amazon. This species commonly found in the Amazon region can reach 10 to 15 m in height and 15 to 20 cm in diameter of trunk. It has the characteristic of presenting flowers and fruits almost all year round. The normally ellipsoid orange fruits, when ripe, are 3 to 5 cm long and have a characteristic odor [3].

2.1 Chemical composition

The sticky and fibrous pulp is very rich in vitamin A, 90 times more than the avocado and 3 times higher than the carrot, also having high vitamin B (thiamine) and high vitamin C content, compared with the citrus fruits. Tucumã also has high energy value (247 calories per 100 grams) and presents relevant content of glycids (19.1%), lipids (16.6%), and proteins (3.5%) [3].

2.2 Biological activity

In addition to good nutritional values, tests were performed on hydroalcoholic, methanolic, and ethanolic extracts in the epicarp of the fruit, and according to Mathias [4], the tucumã presents better antioxidant activity of hydroalcoholic extracts. Thus, the antimicrobial activity of plant extracts was evaluated by determining the minimum inhibitory concentration [5]. However, despite numerous other benefits presented in traditional acknowledgment, the tucumã extracts did not show antimicrobial activity against any of the strains (*Bacillus*, *Enterobacter*, *Enterococcus*, *Escherichia*, *Salmonella*, *Shigella*, *Streptococcus*, *Listeria*, *Staphylococcus*, *Geobacillus*) [4, 5].

In a recent study by Bernardes et al. [6], tucumã presented high medicinal potential due to its composition rich in carotenoids, flavonoids, fibers, and polyunsaturated fatty acids, indicating its use on lipid metabolism and the prevention of disorders from the cardiovascular system. In this study, hyperlipidemia was induced by intraperitoneal injection of Poloxamer 407 in rats resulting in an elevated blood lipid level (hyperlipidemia). Tucumã was not active in reducing these increasing lipids; however, it acts on modulation of purinergic enzymes that could present the ability to keep vascular homeostasis, reducing platelet aggregation and consequent arterothrombosis, which could be converted in reducing of hyperlipidemia and cardiovascular diseases.

According to Azevedo [7] the antimicrobial activity of hexanic and methanolic extracts of tucumã pulp were tested against standard strains of the bacteria *Staphylococcus aureus* (ATCC6538), *Escherichia coli* (ATCC 35218), and *Pseudomonas* *aeruginosa* (ATCC 9027) and against the yeast *Candida albicans* (ATCC 12031) by microplate dilution technique [8]. No antimicrobial activity of the hexanic and methanolic extracts of the tucumã pulp against *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* was observed confirming previous studies, without antibacterial activity [4, 5]. Also, no antimicrobial activity of the hexanic and methanolic extracts of the tucumã pulp was obtained against *Candida albicans* [7].

Tucumã is a fruit rich in bioactive compounds still little explored by the scientific community. Lectins are proteins capable of selective and reversible binding to various carbohydrate types without altering the chemical structure of any glycosyl linker residue. Tucumã mesocarp extract was obtained in 1:3 saline phosphate buffer (PBS) and was studied to verify its lectinic activity on crude extract and its fractions, by a hemagglutination assay which was performed against rabbit, human, and sheep blood. The results pointed to positive lectinic activity only by crude extracts, suggesting that the different fraction could act synergistically in crude extract, but fractioning technique used could have separated the synergistic active principles, making the obtained fractions inactive [9].

One study [10] measured the interference of oils extracted from tucumã in the composition of the dental biofilm and the progress of enamel demineralization and dental caries that is a multifactorial disease that is still prevalent worldwide. With relevant action of microorganisms in biofilm formation on the tooth surface, reducing of dental plaque formation bacteria could be reverted in decreasing of caries. The relationship between biofilm microorganisms and dietary elements (carbohydrates) may influence the etiology of this disease. The study performed an in situ work with volunteers that were kept with dental enamel blocks fixed on their palates, treated with solutions. One group used a sucrose solution (20%) and other groups with sucrose solution added with natural oils including tucumã (20%). Mineral loss of enamel blocks was assessed by Knoop surface microhardness and optical coherence tomography. There was a reduction of the count of cariogenic bacteria *Streptococcus mutans*, total *Streptococcus*, and *Lactobacillus casei* in the tucumã oil group compared with the sucrose control group, and also the mineral loss was lower ($p < 0.05$). These findings present tucumã oil as a potential source of compounds for the manufacture of anticaries drugs in the future [10].

Neuropsychiatric diseases carry with them a complicated pathophysiology, some of which have recently been associated with excess of free radicals compared with each cell's intrinsic protective system (oxidative stress) and mitochondrial dysfunction, resulting in an exacerbated inflammatory response. Due to the complexity of the pathophysiology of neuropsychiatric diseases, research with natural products with bioactive and pharmacological characteristics is necessary, such as the use of nanotechnology to improve the bioavailability of these compounds and with the potential to delay, prevent, and treat such pathologies. In one study [11], tucumã oil nanoemulsions were prepared to help protect their bioactive compounds and improve their biodistribution. The stability of the formulations was tested for 90 days under different storage conditions. The SH-SY5Y and B2 neuronal strains were used to evaluate the safety profile of free tucumã oil and its nanoemulsion, in addition to its power to activate cell proliferation. Based on the results initially observed, tucumã oil nanoemulsion was tested against inflammatory activity in BV-2 cells activated by lipopolysaccharides. The best conservation condition of nanoemulsion was under refrigeration. Regarding cytotoxicity evaluations in BV-2 and SH-SY5Y cells, no significant damage was observed. Regarding the anti-neuroinflammatory effect evaluations of tucumã nanoemulsion, it was observed that although nanoformulation did not maintain cell proliferation levels equal to the negative control, there was a reduction in cell reactivity, oxidative profile normalization, and cell cycle regulation. Thus, it can be suggested that tucumã oil has a potential anti-inflammatory effect and that through its nanostructuring this effect can be optimized and may perhaps overcome the blood–brain barrier and modulate possible chronic inflammatory stimuli that correlate with neuropsychiatric or neurodegenerative disease [11].

3. *Caryocar* sp.

The genus *Caryocar* belongs to the Caryocaraceae family and has species that are popularly known as pequi, piqui, or pequiá. The most studied species of the genus are *Caryocar brasiliense*, *Caryocar villosum*, and *Caryocar coriaceum* [12].

This genus is easily found in Central and South America. According to some authors, the fruit may be called by different names according to the region in which it is found, such as the following: the fruits of *C. brasiliense* that are more commonly found in the Midwest of Brazil and Minas Gerais are called pequi; *C. coriaceum* fruits common in the Northeast of Brazil are called piqui; and *C. villosum* fruits from the Amazon region are called piquiá [13].

Caryocar spp. are a drupaceous fruit, globose, and green in color, with one to four segments [13]. The ripe fruit of pequi is a shell composed of a thin brownish-green exocarp and an outer mesocarp composed of a white, inedible mass. Within the fruit is a nucleus that has an inner mesocarp or inner flesh, the generally edible fruit component, light yellow in color, abundant, oil-rich flesh, and an almond within the spinous endocarp [12, 13].

3.1 Chemical composition

The fruit of pequi is rich in several important components, such as monounsaturated fatty acids (MUFA), bioactive compounds, fibers, minerals [13], and carotenoids [12]. The amount of each may vary according to the species analyzed, the environmental conditions in which it is inserted, the part of the fruit, as well as the type of analysis that was used [13].

The pulp of *Caryocar* spp. has a substantial amount of MUFA, and dietary fiber and minerals are found, of which calcium, magnesium, and potassium stand out. Fruit peel is abundant in dietary fiber, including soluble fiber and phenolic compounds, but in oil high levels of oleic acid are found [12].

Carotenoids are natural pigments of various fruits of Brazil. The presence of this pigment in *Caryocar* spp. occurs with values comparable to those of papaya and guava, which are considered fruits rich in carotenoids. The carotenoids found in the pulp were β-carotene, lycopene, ζ-carotene, cryptoflavin, β-cryptoxanthin, anteraxanthin, zeaxanthin, mutatoxanthin, violaxanthin, lutein, and neoxanthin [13]. However, as stated earlier, the amount present in each species varies due to several factors. In the review of Nascimento Silva and Naves [12], this difference varying between 155 and 270 μg/g of carotenoids in *C. brasiliense* species was found, whereas from *C. villosum* it was between 17 and 69 μg/g.

In the study by Chisté et al. [14], the pulp of *C. villosum* was chemically characterized, and the most representative components were total lipids (25.5% wet basis), gallic acid, ellagic rhamnose, and ellagic acid as the main phenolic compounds and all-trans-antheraxanthin and all-trans-zeaxanthin as the main carotenoids.

Carotenoid profile analysis in pequi pulp has been a challenge for researchers. For best results, various procedures for carotenoid extraction with different solvents, temperatures, time periods, and equipment were performed. In addition to the pulp and species extraction methodology, the ripening stage of the fruit also interferes with the composition, since carotenoid synthesis intensifies during the ripening period. Storage conditions need to be evaluated, as light-protected packaging minimizes compost loss [12].

The extraction of bioactive compounds from plant materials is strongly influenced by the solubility of each specific structure in the solvent used. Knowing this, Chisté et al. [14] evaluated *C. villosum* extracts using different solvents with different polarities, which was ethanol/water (1:1, v/v), ethanol/ethyl acetate (EAC) (1:1, v/v), and ethyl acetate. The extracts produced solid mass ranging from 10.8 to 46.4%, depending on the solvent. The ethyl acetate and ethanol/ethyl acetate extracts showed the highest total lipid content and the highest solid mass yield. The ethanol/water extract presented the highest values of total phenolic compounds (9.2 mg garlic acid equivalent (GAE)/g of lyophilized extract), total flavonoids (3.8 mg catequin equivalent (CE)/g of freeze-dried extract), and total tannins (7.6 mg tannic acid equivalent (TAE)/g of lyophilized extract), followed by the other extracts, ethanol/ethyl acetate and ethyl acetate extracts, that had the lower content of these compounds. This result can be explained considering that the main phenolic acids (gallic acid, ellagic acid and derivatives) found in *C. villosum* pulp have high affinity for high-polarity solvents. In fact, water or ethanol and mixtures between them are widely used for the quantitative extraction of phenolic compounds from different plant sources.

Regarding the total carotenoid content, the ethanol extract presented the highest value (0.1 mg/g), while the ethanol/water mixture presented the lowest value (0.01 mg/g). Since the composition of carotenoids from *C. villosum* pulp has been reported to be primarily hydroxyl groups (xanthophylls), it is more polar than carotenes generally found in large quantities in fruits of the Amazon. This fact explains why the use of high-polarity solvents (such as water and ethanol/water) has low efficiency in carotenoid extraction [14].

In *C. brasiliense* pulp, larger total phenolic compounds were found than in almond. In almond oil of this same species, the values of gallic acid (GAE) were higher, up to 392 mg of GAE/100 g of oil [13].

According to the literature, the total phenolic content of pulp fluctuates even in the same species. Studies with *Caryocar* spp. reported that the total phenolic content ranges from 178 to 334 mg/100 g gallic acid equivalents (GAE), 209 mg/100 g GAE for *C. brasiliense*, and 59 mg/100 g GAE for *C. villosum*. Although the total phenolic content of *C. brasiliense* pulp is the lowest among other species of the genus, it is still higher than Cerrado Biome fruits, such as jenipapo with an average of 48 mg/100 g, and fruits such as banana with 56 mg/100 g or mango with 78 mg/100 g [12].

3.2 Biological activities

In addition to the nutritional benefits, pequi has important biological activities. These include healing, anti-inflammatory, and antimicrobial activities and protection against genome damage and oxidative damage. These benefits are mainly attributed to the presence of MUFA and phytochemical compounds [13].

Gallic acid and ellagic acid are the phenolic compounds most present in *C. villosum* pulp. These compounds suppressed tumors, inhibiting cell proliferation-related gene expression and angiogenesis in 1,2-dimethylhydrazine (DMH)-induced tumors, transgenic prostate adenocarcinoma, and mice-bearing prostate xenografts. In addition to these activities, some epidemiological studies have reported that ingestion of polyphenol-rich sources reduces the risk of developing chronic diseases such as cardiovascular disease, type 2 diabetes, cancer, and neurodegeneration [12].

Carotenoids and phenolic compounds obtained from *C. coriaceum* pulp have important antioxidant action. Active flavonoids have the ability to neutralize pathogens and eliminate reactive oxygen species (ROS) either directly or indirectly, activating pathways that enable ROS degradation [15].

Doxorubicin (DOX), from the anthracycline group, is a drug given to treat cancer. However, it has side effects, such as cardiotoxicity exerted through the production of free radicals. In the study of Moura et al. [16], ethanolic extract of pequi bark (PSEE) was administered daily to DOX-treated rats; this led to increased activity of the enzyme glutathione reductase (GDH-Rd). This enzyme is responsible for maintaining the cellular protection system intact through a biochemical cascade. The presence of elevated GDH-Rd in the heart tissue of PSEE-treated rats showed higher antioxidant activity than those who did not undergo the treatment.

In addition to these effects, there are reports of the leishmanicidal effect of the fruit. Therefore, the search for alternative treatments, including the use of natural products with less toxicity than conventional treatments, has become more frequent [17].

In leishmaniasis disease, an inflammation must occur to control the parasitic load, being triggered by the interaction of the parasite with the host immune cells. However, an exacerbated response can cause tissue damage, similar to those seen in leishmaniasis. Thus, an antioxidant action of *C. coriaceum* controls the inflammatory response for effective disease control [15].

The study by Tomiotto-Pellissier [17] aimed to verify the leishmanicidal action of *C. coriaceum* leaf extracts obtained from extraction by EAC and methanol (MET). The extracts were able to induce the parasite mitochondria membrane depolarization in the promastigote phase; such membrane is crucial for parasite survival, since *Leishmania* spp. have a single mitochondria, which is the main site for generating cellular ATP through oxidative phosphorylation, making it a promising antiparasitic target. Mitochondrial respiratory chain dysfunction can produce an enormous amount of ROS within the organelles. Both EAC and MET promoted the increase of ROS in the promastigote phases. In addition, the cascade triggered by loss of mitochondrial integrity followed by increased ROS production can lead to parasite death through an apoptosis-like mechanism. The results showed that although both extracts had similar results, the treatment with EAC was a more efficient activity against promastigote forms than MET. The presence of catechins and steroids only in the EAC extract, and the greater amount of flavonoids than MET, could explain the more pronounced results found in the treatment with EAC. In addition, the effects could be given by the synergistic action of the compounds present in the extracts.

Its antimicrobial effect has been tested by Alves et al. [15]. The ethanolic extracts of peel and pulp of *C. coriaceum* had activity against six pathogenic strains, three of the genus *Malassezia* sp., and three from *Microsporum canis*. The minimum fungicidal concentration (MFC) and the minimum inhibitory concentration (MIC) were 39.1 μg/mL (MFC) and 9.8 μg/mL to 19.5 μg/mL (MIC) against *Malassezia strains* and 4.9 to 9.8 μg/mL (MFC) and 4.9 μg/mL (MIC) against *M. canis*. Besides that, the authors evaluated the antioxidant activity the extracts compared with a standard (rutin), obtaining higher activity of the extracts, with highlight to the pulp extract that had activity 3.6 times higher than rutin.

4. *Hymenaea* sp. (Jatobá)

Jatobá (*Hymenaea* sp.) belongs to the family Fabaceae and subfamily Caesalpiniodeae and has been highlighted for a long time by folk medicine. The word jatobá has its origin from the Tupi language of Brazilian Indians, meaning "hard fruit tree," and this species is used for various purposes, such as medicinal, food, ornamental, and timber use [18]. Its distribution occurs in Central America to South America, mainly in the Amazon basin, and this genus comprises about 25 described species in America [19].

The use of this plant for medicinal purposes is not restricted to the use of its leaf or fruit extracts. The structures used are the most diverse as stem bark, leaves, and roots and are prepared, for example, by infusion, cooking, maceration and syrup for phytotherapeutic extraction, and isolation of the active compounds. Such extracts can be used for anti-inflammatory, healing, soothing, influenza, cough, pneumonia, gastritis, ulcer, burning urethra, stroke, anemia, and more, showing how this plant is extremely important for culture and traditional popular medicine in Brazil [18].

4.1 Chemical composition

The species *Hymenaea stigonocarpa* was studied by Cardoso et al. [20] to analyze the nutritional content of pulp of fruits. The results pointed to low pulp yield (17.1%) and moisture (8.8 g/100 g) and a rich presence of dietary fiber (44.3 g/100 g), energy (193.0 kcal/100 g), and protein (5.6 mg/100 g). Vitamin E and folates were present in higher levels than other common fruits (53.5 and 495.5 μg/100 g, respectively). Carotenoids and vitamin C were present in low concentrations (0.4 mg and 8.9 mg/100 g, respectively). The authors concluded that the fruit of this species known as "jatobá of cerrado" is a source of vitamin C, a good source of folates, and an excellent source of dietary fiber.

In the work of Veras et al. [19], leaves of *H. cangaceira* were hydrodistilled to obtain a yellow essential oil. Within this oil 15 compounds were detected, which were 85.38% of the total composition of the oil. The analysis of the composition of this oil presents a high percentage of sesquiterpenes (79.04%), besides having as main components ß-caryophyllene (23.38 ± 0.51%), germacrene D (14.66 ± 0.14%), α-guaiene (9.75 ± 0.07%), β-elemene (7.05 ± 0.02%), α-copaene (6.34 ± 0.15%), and α-humulene (4.65 ± 0.12%) [19].

Aguiar et al. [21] evaluated chemical composition of ripe and unripe peels of *H. courbaril*, founding sesquiterpenes as main compounds of both samples (86.1 and 93.3%, respectively). In ripe peels majority of the compounds were α-copaene (11.1%), spathulenol (10.1%), β-selinene (8.2%), γ-muurolene (7.9%), and caryophyllene oxide (6.9%); unripe samples provided an oil with germacrene D (31.9%), β-caryophyllene (27.1%), bicyclogermacrene (6.5%), α-humulene (4.2%), and α-copaene (4.2%) as the major compounds.

The crude ethanolic extract and ethyl acetate fraction obtained from stem barks of a tree of *H. martiana* was analyzed for the identification of flavonoid content. The results showed 11 peaks in the chromatograms that were identified as taxifolin, eucryphin, astilbin and three diastereoisomers, engeletin and two diastereoisomers, quercitrin, and 2,6,3′,4′-tetrahydroxy-2-benzylcoumaran-3-one. The ethyl acetate fraction presented 3.8 times higher concentration of astilbin than the crude extract [22].

4.2 Biological activities

Veras et al. [19] stated that the biological effects of the compounds described above (*H. cangaceira*) are as follows:·caryophyllene has anti-inflammatory, antibacterial, antifungal, antirheumatic, antioxidant, antitumor, analgesic, and antiviral activities. Germacrene has been described with antitumor, analgesic, anti-inflammatory, and antioxidant activities, as well as α-amylase and acetylcholinesterase inhibitory activity. Guaiene has reports as a cyclooxygenase inhibitor, 5-lipoxygenase, and acetylcholinesterase and has antioxidant and anti-inflammatory activities. Elemene is described as potent antimicrobial, antioxidant, and anesthetic. Copaene has antimicrobial, antileishmanial, antigenotoxic, and antioxidant activities. Humulene is referred as an anti-inflammatory, analgesic, and antiallergic agent [19].

In a research conducted by the Federal Rural University of Pernambuco, the effectiveness of the essential oil of jatobá leaf (*H. cangaceira*) against *Staphylococcus aureus* ATCC 43300 (MRSA), *S. aureus* ATCC 29213 (MSSA), *Pseudomonas aeruginosa* ATCC 27853, *Klebsiella pneumoniae* ATCC 700603, *Candida tropicalis* ATCC 750, and *C. krusei* ATCC 6258 was observed. The result of inhibition of both fungi and bacteria was positive for the oil of jatobá in different concentrations, and it must highlight the high activity against Gram-negative bacteria with MICs ranging between 4 and 16 μg/mL, result similar to cefepime, the control drug used [19]. The same authors also present in this work other important bioactivities, such as high antioxidant and analgesic activities and absence of toxicity on rats and erythrocytes.

In other work from the Federal University of Sergipe, *H. martiana* leaf extract was tested in inhibition of isolates of *Salmonella* spp*.*, *Escherichia coli*, and *Staphylococcus aureus* and reduces its counts in raw milk. The minimum bactericidal concentrations (MBC) against bacteria were 125.3 μg/mL against *S. aureus* (ATCC 25923), 781.2 μg/mL against *E. coli* (ATCC 35218), and 1556.5 μg/mL against *S. enterica* subsp. *enterov* serovar Choleraesuis ATCC® 10708. The authors inoculated these bacteria on milk samples at different concentrations and used the extract in MBC concentrations to try to avoid bacterial growing on milk. However the results were not as expected, since there was growing of bacteria in concentrations of 10^4 and 10^6 UFC/mL. Only in lower concentration of bacteria on milk does inhibition on growing of bacteria occur. The author suggests that the biological compounds present in milk may have reacted with the bioactive compounds of the extract, reducing their antibacterial activity [23].

Aguiar et al. [21] evaluated the activity of essential oil of ripe and unripe fruits of *H. courbaril*, as larvicide against *A. aegypti* larvae. The oil from ripe fruits was a strong larvicide against the larvae, presenting death of 50% of larvae with almost half of the concentration necessary for unripe fruit oil to obtain the same result (LC50 14.8 + 0.4 and 28.4 + 0.3 μg/mL). The authors assigned this difference to the higher concentration of oxygenated sequiterpenes in first oil, mainly spathulenol.

5. *Mammea americana* (apricot)

Mammea americana, popularly known as apricot, wild apricot, or apricot from São Domingos, is a fruit originating from the West Indies and northern South America, currently found mainly in the Amazon and some few other regions [24].

According to a study by Mourão and Beltrati [25], in which they characterized the morphology and anatomy of the fruit, it was possible to typify the apricot as a berry, whose "bark" consists of the epicarp and mesocarp that together represent 13.3% of the fruit's weight. The endocarp represents 70.7%, and the remainder of the fruit is represented by the large seeds, which account for 16% of the fruit weight [26].

The first commercial orchards were established in the mid-1980s, with seedlings that originated from seeds. Due to this fact, there was a large proportion of male plants and several phenotypic variations in the chemical and physical characteristics of the fruits. As an example, from a sample of 50 fruits originating from

10 different mother plants, it was possible to identify an average fruit weight of 852.8 g, with minimum and maximum limits of 502.3 g and 1443.0 g. Thus, it is possible to verify that the fruit weight is derived from the genetic origin trait, although it suffers a lot of influence from the environment [26].

The apricot tree can be disseminated through a sexual or asexual route. However, being a species that presents male plants and hermaphrodite plants, the orientation is that their diffusion is effected by vegetative processes. Thus, the most widely used method is grafting. Its spread by grafting ensures early production and enables the orchard to have only hermaphrodite plants [27].

It is grown in igapós and flooded river banks in the Amazon region, mainly in the state of Pará. It's a medium-sized tree that can reach 20 m in height; the apricot easily propagates through seeds, which germinate between 12 and 18 days. The plant can start flowering from 6/8 years [28].

5.1 Chemical composition

Through the study by Nascimento [29], it was possible to identify the composition of apricot, which has a vitamin content of 27.26 ± 1.03 mg of ascorbic acid/100 g in the apricot pulp. It was also possible to characterize the carotenoid content in apricot pulp which was 161.34 ± 0.40 bs and dehydrated product 103.53 ± 0.65 bs (μg/100 g β-carotene). By analyzing the results of quantifying antioxidant activity from the substitution calculations in the equation of the Trolox curve line, according to the ABTS method, a value of 31.96 ± 0.76 μM Trolox/g bs was obtained from fresh apricot. The analyses that dealt with the quantification of antioxidant activity from the consumption calculations of the DPPH radical obtained a value of 192.51 ± 0.13 fruit/g DPPH bs in the apricot sample in natura.

5.2 Biological activity

Regarding its biological activity, it is possible to identify, through studies found in the literature, extracts of *Mammea americana* generating results in the medical field.

According to studies by Toma et al. [30] that analyze the action of apricot extracts as antiulcerants in mice, the extracts showed antiulcerogenic effects with significant reduction in the damage of gastric lesions through the model of anti-inflammatory-induced injury. In NSAID/cholinomimetic-induced model, ethanolic and dichloromethane extracts of apricot showed antiulcerogenic effects with significant reduction in the damage of these gastric lesions by 36 (8.3 ± 2.0 mm) and 42% (7.5 ± 1.4 mm), respectively, as compared to the control group (13.0 ± 0.9 mm), increased the pH values, and promoted reduction of acid production.

According to the studies by Braga et al. [31], the antioxidant activity and the quantification of bioactive compounds (total carotenoids, CT; total polyphenols, PT; and total flavonols, FT) and the physical and centesimal characterization of the compounds of apricot fruits (*Mammea americana*) were evaluated. Antioxidant activity was measured by two different methods, oxygen radical absorbance capacity (ORAC) and the Trolox equivalent antioxidant capacity (TEAC). By ORAC, the results showed antioxidant activity with results of 30.97 ± 2.30 μmol equivalent Trolox/100 g, within the results showed of acerola (*Malpighia emarginata*) according the authors. In the TEAC test, the result was 11.82 ± 1.40 μmol equivalent Trolox/100 g, inside the range of acai also. For these two methods, the antioxidant activity of apricot was lower than other fruits like murici (*Byrsonima crassifolia*) and ingá (*Inga* spp.) For the bioactive compounds present in apricot in this work, 2.61 ± 0.73 mg equivalent catechin/100 g of FT, 25.41 ± 2.30 mg equivalent gallic acid/100 g of PT, and 7.55 ± 0.78 mg equivalent β-carotene/100 g CT were found.

From these results, the high content of carotenoids must be highlighted, which indicate that apricot is a promising source of pro-vitamin A.

According to a study found in the literature, it was possible to identify high trypanocidal activity in extracts of *Mammea americana*. In this way, compounds were obtained from *M. americana* fruit peels, and their action against the parasite was tested. The compounds were tested in vitro against epimastigotes (intracellular phase, without locomotion organelles, with little cytoplasm and large nucleus) and trypomastigotes (extracellular phase, circulating in the blood) of *Trypanosoma cruzi*, the etiological agent of Chagas disease. The most potent compounds were mammea A/BA, A/BB, A/AA, A/BD, and B/BA (designation based on chemical characteristics), with MC100 (minimum concentration at which all of the epimastigotes or trypomastigotes died after a 48-hour incubation) values ranging between 15 and 90 g/ml. Several active coumarins were also tested against normal human lymphocytes in vitro, which showed that mammea A/AA and A/BA did not show toxicity. Thus, through this study, it was possible to identify that these mammea-type coumarins have trypanocidal action and if they deepen the study of the compound, it may become possible to identify an important source of compounds with trypanocidal action [32].

6. *Platonia insignis* Mart (Bacuri)

Platonia insignis Mart consists of a species in the Clusiaceae family, being popularly named as bacuri. It has a fruit of appreciated flavor and is very famous in the Amazon region. The generic name, *Platonia,* is a tribute to the philosopher Plato (in Portuguese, Platão), and insignis means remarkable in reference to the size of the fruit [33]. The bacuri belongs to the subfamily Clusioideae and the genus Platonia and encompasses about 1000 species, present in tropical, subtropical, and temperate regions of the world. Approximately 90 species correspond to plants, involving trees, shrubs, lianas, and herbs of economic interest for the production of edible fruits, fine woods, and chemical derivatives of pharmaceutical and industrial interest [34–37].

Ethnobotanical utility concerns the use of oil extracted from its seeds, such as in the production of soap and as anti-inflammatory. The seeds are used to make bacuri oil, which is popularly used in the treatment of skin diseases and as a wound healer in animals. It is noteworthy that the investigation of *P. insignis* extracts and compounds is based on popular use. However, pharmacological studies conducted with the plant point to it as promising source for elaboration of phytomedicines with healing, anti-inflammatory, anticonvulsant, antimicrobial, cytotoxic, and antioxidant activities and to be used in treatment of several diseases such as cancer, Alzheimer, and Parkinson [38].

6.1 Chemical composition

Rocha [39] evaluated the chemical composition of *Platonia insignia* leaves and classified the chemical constitution as positive, moderately positive, strongly positive, or negative, as can be seen in **Table 1**.

6.2 Biological activity

Phenolic compounds present in the extract, such as catechins and flavononols, are widely distributed in the plant kingdom and associated with various biological activities, such as the fact that flavonoids have activity on capillary, anti-inflammatory, antiviral, antitumor, and hormonal permeabilities [40, 41]. Among the phenolic

Coumarins	Presence of substances
Phenols	Strongly positive
Condensed tannins	Strongly positive
Catechins	Strongly positive
Steroids	Strongly positive
Alkaloids	Strongly positive
Flavanonols	Moderately positive
Saponins	Moderately positive
Coumarins	Negative
Hydrolyzable tannins	Negative
Anthocyanidins and anthocyanidins	Negative
Flavones, flavonols, and xanthones	Negative
Chalcones and aurones	Negative
Leucoanthocyanidins	Negative
Flavonones	Negative
Triterpenoids	Negative

Note: Results expressed as average of the qualitative and semiquantitative evaluation tests of chemical constituents performed in triplicate in the hydroalcoholic extract, by Rocha [39]. Strongly positive; moderately positive; positive; negative. Source: in [39], adapted.

Table 1.
Qualitative and semiquantitative evaluation of the chemical constituents in the hydroethanol extract of Platonia insignis *Mart leaves.*

compounds, flavonoids were found in large quantities in bacuri extract, which exhibit several biological properties, such as anti-inflammatory, hormonal, and antioxidant action [42].

In addition, saponins can be found in tissues susceptible to bacteria, fungi or insects, due to their relationship with the plant defense system. This substances have hemolytic activity, formed with hypocholesteromic antifungal action and with the ability to change the permeability of membranes [41, 43, 44].

Alkaloids, in turn, are known for their antimalarial, antimicrobial, and cytotoxic activities [45]. Moreover, according to [46] review, *P. insignis* has antiepileptic and vasorelaxant activity.

Finally, there are compounds in bacuri, such as kaempferol and quercetin glycosides, that express significance in the regulation of hyperglycemia, due to the strong stimulation of glucose and oleic acid absorption [47].

7. Conclusion

Given the information previously constructed, it is possible to infer, therefore, that the Amazon rain forest has a considerable diversity of plants, which have several biological activities that may be of great concern for public health application. This is a little example of the power of biodiversity present in the Brazilian Amazon and of the natural resources with biopotential for treatment of a large number of diseases, being a promising source of new drugs that could be alternatives for the traditional drugs used nowadays that present side effects, such as toxicity to the patient and emergence of bacterial resistance to antibiotics, among others. Thus, many new studies are needed to identify compounds with desirable health activities, and the Amazon, by their potential biodiversity, seems to be the best place to look.

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References

[1] Borellli DL. Aziz Ab'Sáber: Problemas da Amazônia brasileira. Estudos Avançados. 2005;**19**(53):7-35

[2] Alho CJR. Importância da biodiversidade para a saúde humana: Uma perspectiva ecológica. Estudos Avançados. 2012;**74**:151-166. DOI: 10.1590/S0103-40142012000100011

[3] da Amazônia P. Tucumã [Internet]. Available from: http://www.amazoniadeaaz.com.br/sem-categoria/o-que-e-tucuma/ [Accessed: 05 November 2019]

[4] Mathias CS. Estudo químico e atividades biológicas dos frutos de tucumã (*Astrocaryum aculeatum Meyer*) [dissertation]. Manaus: Universidade Federal do Amazonas; 2014

[5] Pinto TJA, Kaneko TM, Ohara MT. Controle Biológico de Qualidade de Produtos Farmacêuticos, Correlatos e Cosméticos. 2nd ed. São Paulo: Atheneu Editora; 2003. p. 325

[6] Bernardes VM. Efeito do tucumã (*Astrocaryum aculeatum*) no metabolismo de nucleotídeos e nucleosídeo de adenina em plaquetas de ratos com hiperlipidemia induzida [thesis]. Santa Maria-RS: Universidade Federal de Santa Maria; 2018

[7] Azevedo SCM. Estudo do potencial biotecnológico da polpa de tucumã (*Astrocaryum aculeatum*) *in* natura e da conservação das suas propriedades nutricionais em embalagens a vácuo [dissertation]. Manaus: Universidade do Estado do Amazonas; 2016

[8] CLSI. Performance Standards for Antimicrobial Susceptibility Testing; Twenty-Fourth Informational Supplement. Wayne, PA: Clinical and Laboratory Standards Institute; 2014. 34:1. p. 226

[9] Aragão AB, Thomaz SMOBB. Purificação e avaliação da atividade lectínica do extrato de tucumã (*Astrocaryum vulgare Mart*.) nativo da região Amazônica. Journal of Basic and Applied Pharmaceutical Sciencies. 2015;**36**(S1):20

[10] Emmi DT. Influência dos óleos do tucumã (*Astrocaryum vulgare*) e da pupunha (*Bactris gasipae*) na composição do biofilme dental e dinâmica do processo de cárie em esmalte: um estudo *in* situ [thesis]. São Paulo: Universidade de São Paulo; 2013

[11] Ramos AP. Nanoemulsão do óleo do tucumã (*Astrocaryum vulgare mart*.) como agente neuroprotetor *in* vitro [thesis]. Santa Maria-RS: Universidade Franciscana; 2019

[12] Nascimento-Silva NRRD, Naves MMV. Potential of whole Pequi (*Caryocar spp*.) fruit-pulp, almond, oil, and Shell-as a medicinal food. Journal of Medicinal Food. 2019;**2**:952-962. DOI: 10.1089/jmf.2018.0149

[13] Torres LRO, Santana FC, Shinagawa FB, Mancini-Filho J. Bioactive compounds and functional potential of Pequi (*Caryocar spp*.), a native brazilian fruit: A review. Grasas y Aceites. 2018;**69**:E257. DOI: 10.3989/gya.1222172

[14] Chisté RC, De Toledo Benassi M, Mercadante AZ. Efficiency of different solvents on the extraction of bioactive compounds from the amazonian fruit *Caryocar villosum* and the effect on its antioxidant and colour properties. Phytochemical Analysis. 2013;**25**: 364-372. DOI: 10.1002/pca.2489

[15] Alves DR, Morais SM, Tomiotto-Pellissier F, Miranda-Sapla MM, Vasconcelos FR, Silva ING, et al. Flavonoid composition and biological activities of ethanol extracts of *Caryocar coriaceum* Wittm., a native plant from

Caatinga biome. Evidence-based Complementary and Alternative Medicine. 2017;**2017**:1-7. DOI: 10.1155/2017/6834218

[16] Moura LR, Viegas AA, Almeida LM, Neves REJ, Lima CS, Moura VMBD. Effect of Pequi shell ethanolic extract on glutathione reductase activity in rats exposed to doxorubicin cardiotoxicity. Revista Brasileira de Medicina Veterinária. 2018;**40**:e89018. DOI: 10.29374/2527-2179.bjvm89019

[17] Tomiotto-Pellissier F, Alves DR, Miranda-Sapla MM, de Morais SM, Assolini JP, da Silva Bortoleti BT, et al. *Caryocar coriaceum* extracts exert leishmanicidal effect acting in promastigote forms by apoptosis-like mechanism and intracellular amastigotes by Nrf2/HO-1/ferritin dependent response and iron depletion: Leishmanicidal effect of *Caryocar coriaceum* leaf exracts. Biomedicine & Pharmacotherapy. 2018;**98**:662-672. DOI: 10.1016/j.biopha.2017.12.083

[18] Silva MR, Lamarca EV. Registros etnobotânicos e potenciais medicinais e econômicos do jatobá (*Hymenaea courbaril*). Revista Ibirapuera. 2018;**15**:8-12

[19] Veras BO, Oliveira MBM, Oliveira FGS, Santos YQ, Oliveira JRS, Lima VLM, et al. Chemical composition and evaluation of the antinociceptive, antioxidant and antimicrobial effects of essential oil from Hymenaea cangaceira (Pinto, Mansano & Azevedo) native to Brazil: A natural medicine. Journal of Ethnopharmacology. 2019;**247**:112265. DOI: 10.1016/j.jep.2019.112265

[20] Cardoso LM, Bedetti SF, Ribeiro SMR, Esteves EA, Pinheiro-Sant'ana HM. 'Jatobá do cerrado' (*Hymenaea stigonocarpa*): Chemical composition, carotenoids and vitamins in an exotic fruit from the Brazilian Savannah. Fruits. 2013;**68**:95-107. DOI: 10.1051/fruits/2013056

[21] Aguiar JCD, Santiago GMP, Lavor PL, Veras HNH, Ferreira YSF, Lima MAA, et al. Chemical constituents and Larvicidal activity of Hymenaea courbaril fruit Peel. Natural Product Communications. 2010;**5**(12):1977-1980. DOI: 10.1177/1934578X1000501231

[22] Pacheco AGM, Branco A, Câmara CA, Silva TMS, Silva TMG, Oliveira AP, et al. Identification of flavonoids in Hymenaea martiana Hayne (Fabaceae) by HPLC-DAD-MSn analysis. Natural Product Research. 2019;**8**:1-6. DOI: 10.1080/14786419.2019.1672062

[23] Santana TC. Uso do extrato de folhas do Jatobá (*Hymenaea martiana Hayne*) na redução das contagens de *Salmonella spp*., *Escherichia coli* e *Staphylococcus aureus* em leite cru [dissertation]. São Cristóvão: Universidade Federal de Sergipe; 2015

[24] Cavalcante PB. Frutas comestíveis da Amazônia. 5th ed. Belém: Edições CEJUP/Museu Paraense Emílio Goeldi; 1991. p. 279

[25] Mourão KSM, Beltrati CM. Morphology and anatomy of developing fruits and seeds of *Mammea americana L*. (*Clusiaceae*). Revista Brasileira de Biologia. 2000;**60**:701-711. DOI: 10.1590/S0034-71082000000400023

[26] Carvalho JEU, Muller CH. Biometria e rendimento percentual de polpa de frutas nativas da Amazônia. Comunicado Técnico 139. Belém-PA: Embrapa Amazônia Oriental; 2005. p. 4

[27] VIillachica H, Carvalho JEU, Müller CH, Diaz SC, Almanza M. Frutales y hortalizas promissorios de la Amazonia. Lima: TCA-SPT; 1996. p. 367

[28] Brasil. Alimentos regionais brasileiros. 2nd ed. Brasília–DF: Ministério da saúde; 2015. p. 481

[29] Nascimento CS. Obtenção de Abricó (*Mammea americana L.*) desidratado

utilizando Secagem por Refractance Window [dissertation]. Belém: Universidade Federal Do Pará; 2015

[30] Toma W, Hiruma-Lima CA, Guerrero RO, Brito AR. Preliminary studies of *Mammea americana* L. (Guttiferae) bark/latex extract point to an effective antiulcer effect on gastric ulcer models in mice. Phytomedicine. 2005;**12**:345-350. DOI: 10.1016/j.phymed.2003.06.009

[31] Braga ACC, Silva AE, Pelais ACA, Bichara CMG, Pompeu DR. Atividade Atioxidante e Quantificação de Compostos Bioativos Dos Frutos De Abricó (*Mammea Americana*). Alimentação e Nutrição. 2010;**21**:31-36

[32] Reyes-Chilpa R, Estrada-Muñiz E, Vega-Avila E, Abe F, Kinjo J, Hernández-Ortega S. Trypanocidal constituents in plants: 7. Mammea-type coumarins. Memórias do Instituto Oswaldo Cruz. 2008;***103***:431-436. DOI: 10.1590/s0074-02762008000500004

[33] Yamaguchi KKL, Lamarão CV, Lima ES, Veiga-Junior VF. Química e Farmacologia do Bacuri (*Platonia insignis*). Scientia Amazonia. 2014;**3**:39-46

[34] Brummit RK. Vascular Plant Families and Genera. Kew: Royal Botanic Gardens; 1992. p. 804

[35] Barroso GM, Peixoto AL, Ichaso SLF, Guimarães EF. Sistemática de angiospermas no Brasil. Vol 1. 2nd ed. Viçosa, MG: Editora UFV; 2002. p. 309

[36] Joly AB. Botânica: Introdução à taxonomia vegetal. 11th ed. São Paulo: Editora Nacional; 1993. 777p

[37] Yaacob O, Tindall HD. Mangoste encultivation. Rome: Plant eProduction and Protection Paper; 1995. p. 100

[38] Santos Júnior RQ, Soares LC, Maia-Filho ALM, Araujo KS, Santos IMSP, Costa-Junior JS, et al. Estudo histológico da cicatrização de feridas cutâneas utilizando a banha de bacuri (*Platonia insignis Mart.*). ConScientiae Saúde. 2010;**9**:575-581

[39] Rocha ES. Produção de bioprodutos com atividade antimicrobiana a partir do extrato das folhas de *Platonia insignis* Mart. (Bacuri) [Thesis]. Tocantins: Universidade Federal do Tocantins; 2017

[40] Castelo KFA. Estudo químico dos extratos ativos de bacuri (*Platonia insignis*) [dissertation]. Manaus: Universidade Federal do Amazonas; 2018

[41] Simões CMO, Shenkel EP, Mello JCP, Mentz LA, Petrovick PR. Farmacognosia: Da planta ao medicamento. 5th ed. Porto Alegre-Florianópolis: Editora da UFSC; 2004. p. 1102

[42] Dovichi SS, Lajolo FM. Flavonoids and their relationship to diseases of the central nervous system. Nutrire: Revista da Sociedade Brasileira de Alimentação e Nutrição. 2011;**36**:123-135

[43] Wina E, Muetzel S, Becker C. The impact of Saponins or Saponin-containing plant materials on ruminant production - a review. Journal of Agricultural and Food Chemistry. 2005;**53**(21):8092-8105. DOI: 10.1021/jf048053d

[44] Araújo LLN, Fari MJM, Safadi GMVV. Prospecção fitoquímica da espécie *Justicia pectoralis* Jacq. var. stenophylla leonard pertencente à família Acanthaceae. Revista Eletrônica de Ciências Humanas, Saúde e Tecnologia. 2014;**3**(2):4-14

[45] Oloyede KG, Oke MJ, Raji Y, Olugbade T. Antioxidant and anticonvulsant alkaloids in *Crinum ornatum* bulb extract. World Journal of Chemistry. 2012;**5**:26-31

[46] Silva APSCL, Araújo LC, Melo BC, Silva-Filho JCCL, Oliveira MCP, Oliveira GLS, et al. *Platonia insignis* Mart with pharmacological applications to the central nervous system: A review. Boletim Informativo Geum. 2016;**7**:24-31

[47] Ho GT, Kase ET, Wangensteen H, Barsett H. Effect of phenolic compounds from elderflowers on glucose-and fatty acid uptake in human myotubes and HepG2-cells. Molecules. 2017;**22**:90. DOI: 10.3390/molecules22010090