
**Tucumã of Pará oil: Chemical profile, biological activities, and
methods of extraction**

**Óleo de tucumã do Pará: perfil químico, atividades biológicas, e métodos de
extração**

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ABSTRACT

The present work research involves a systematic review of the chemical profile and biological activities of vegetable oil from the *Astrocaryum* species identified in Brazilian amazon rainforest. *Astrocaryum* consists of a important group of botanical species that have economic value in the national and international fruit market. Furthermore, the species has application in several areas such as pharmacology, biotechnology, and medicine. In folk medicine, species such as *Astrocaryum aculeatum* M. and *Astrocaryum vulgare* M. are used in prevention of diabetes and inflammatory diseases. The species of *Astrocaryum* are natural source of vegetable oil and are rich in bioactive compounds belonging to the classes of carotenoids, of these compounds β -carotene is the most abundant. The cytoprotective, anti-inflammatory and antimicrobial activities of vegetable oils from the *Astrocaryum* species in Brazilian amazon rainforest have been described in previous research.

Keywords: *Astrocaryum vulgare*; Chemical profile; Biological activities; Amazon fruit.

RESUMO

O presente trabalho de pesquisa envolve uma revisão sistemática do perfil químico e das atividades biológicas do óleo vegetal da espécie *Astrocaryum* identificada na floresta amazônica brasileira. *Astrocaryum* consiste em um importante grupo de espécies botânicas que possuem valor econômico no mercado nacional e internacional de frutas. Além disso, a espécie tem aplicação em diversas áreas como farmacologia, biotecnologia e medicina. Na medicina popular, espécies como *Astrocaryum aculeatum* M. e *Astrocaryum vulgare* M. são utilizadas na prevenção de diabetes e doenças inflamatórias. As espécies de *Astrocaryum* são fonte natural de óleo vegetal e são ricas em compostos bioativos pertencentes às classes dos carotenoides, destes compostos o β -caroteno é o mais abundante. As atividades citoprotetoras, anti-inflamatórias e antimicrobianas de óleos vegetais da espécie *Astrocaryum* na floresta amazônica brasileira já haviam sido descritas em pesquisas anteriores.

Palavras-chave: *Astrocaryum vulgare*; Perfil químico; Atividades biológicas; Fruta amazônica.

INTRODUCTION

The Amazon, known worldwide for its biodiversity, is considered one of the greatest bioeconomic potentials in the world to generate wealth in different formats, including for companies seeking to explore its biodiversity, obtain products with high added value and even discover new applications for it. With the adaptation of industrialization in the sustainable economy format, which has modernity such as robotics and automation in technological processes, there is room to assess the potential of other plant species native to the Amazon region, such as tucumã-do-Pará (*Astrocaryum vulgare* Mart.), and other technologies without harming the native forest of the Amazon region.

Tucumã-of-Pará (*Astrocaryum vulgare* Mart.) is an Amazonian palm fruit, a natural source of vegetable oil and, like other palm fruits, such as palm oil (*Elaeis guineensis*), it contains high concentrations of β -carotene (MATOS et al., 2019; SANTOS et al., 2013). After an analysis of the Brazilian Agricultural Research Corporation (Embrapa) reports, which can be consulted through the link <https://www.embrapa.br/biblioteca>, it was found that tucumã-of-Pará is listed among the richest Brazilian natural sources of β -carotene, together with palm oil (*Elaeis guineensis*) and all these listed qualities confer functional quality for tucumã-of-Pará oil to be a sustainable substitute for palm oil, whose excessive consumption has caused destruction of tropical forests to expand your plantation.

The need to assess the oleaginous potential of other species native to the Amazon region, such as tucumã-of-Pará (*Astrocaryum vulgare* Mart.), is reinforced by Embrapa research reports that indicate palm oil (*Elaeis guineensis*) as the only fruit of the Amazon capable of meeting the Brazilian demand for 100 million tons of vegetable oil by 2035. The strategic potential of using tucumã-of-Pará as a promising source of vegetable oil is reinforced by studies that estimate the tucumã-of-Pará productivity at 1.7 tons of oil/hectare/year, possibly reaching up to 50% of the palm oil productivity, which is 4 to 6 tons of oil/hectare/year (SANTOS et al., 2013).

Tucumã-of-Pará oil is also a nutritional source, as it is an oil rich in polyunsaturated fatty acids, when compared to palm oil. Polyunsaturated fatty acids, such as oleic acid, and other bioactive compounds, such as β -carotene and polyphenols, provide a functional quality for the fruit to have an aroma, flavor, and texture that is pleasant to the palate, in addition to making the fruit nutritious and beneficial to human

health (FERREIRA et al., 2008; SANTOS et al., 2017). These adjectives contribute to the oil being exploited in gastronomy for the preparation of fish-based dishes typical of the Amazon region, in addition to providing functional quality for the oil to be applied in popular medicine as a source of substances with proven biological activity (DIDONET and FERRAZ, 2014; FERREIRA DE OLIVEIRA et al., 2018).

This present work intends to encourage the sustainable exploration of the tucumã-of-Pará mesocarp oil and show that the tucumã fruit is a promising source of high-quality oil through the presentation of scientific papers that showed the chemical profile and biological potential of the tucumã-of-Pará oil.

BOTANICAL CHARACTERISTICS

Astrocaryum vulgare Mart. is a species of palm tree that belongs to the *Arecaceae* family and can be found in natural environments of the Amazon rainforest, such as in the savannah regions and on sandy coastal ridges forest, due to its ability to adapt well to different types of lands (KAHN, 2008). However, although this palm has a good adaptive capacity to different terrains, the tree of this species is commonly found in dry land areas, where there are no flooded soils, and in these areas, the density can reach 50 or more individuals per hectare (SCHROTH et al., 2004). *A. vulgare* Mart. tree, popularly known as “tucumanzeiro”, is a large single-stemmed palm that can reach up to 20 meters in height and its trunk can have a diameter ranging from 15 to 20 centimeters (KAHN, 2008).

Generally, palms are moderately fire-tolerant and can then develop through progressive shifting cultivation cycle. Considering this current scenario, which highlights the importance of sustainability in the preservation of the Amazon's native forest, it should be considered that there is a huge production chain of palm oil (*Elaeis guineensis*) in the Amazon region, whose large-scale production requires the degradation of some areas of native forest to cultivate many hectares of plantation. One of the many solutions to replace palm oil is the use of existing agricultural crops such as the tucumã-do-Pará (*Astrocaryum vulgare* Mart.), given its economic, ecological and food potential that it represents for the region. Tucumã-do-Pará planting in Brazil is found in the Amazon region through an agroforestry system that is sustainable, does not produce guaranteed damage to the existing vegetation cover and maintains areas of native forest, unlike oil

palm (SCHROTH et al., 2004). The figure 1 shows a “tucumanzeiro” which was planted inside the forest together with other vegetable species. The photo was taken in Brazilian municipality of Bujaru, state of Pará, Brazil.

Figure 1 - Palm tree of the *Astrocaryum vulgare* Mart. species



Source: The authors (2021)

The thorns present on the trunk could be a harmful characteristic in agricultural fields and pastures, if it weren't for their fruits that generated an important trade developed in the Brazilian states of Manaus and Pará (DIDONET and FERRAZ, 2014; SCHROTH et al., 2004). The tucumã-of-Pará fruits grow on the palm clusters, and it can reach more than 1 meter in length and produce more than 200 fruits, on average per cluster and reach an average production of up to 750 fruits per palm (FERREIRA DE OLIVEIRA et al., 2018).

However, although there is an interesting market for the fruits of this species, plantation agriculture has been less favored in relation to tucumã extraction, mainly due to the slow germination of seeds, which can last from 8 months to 2 years. To cause tucumã seeds germination and increase the density of spontaneous palm populations, some farmers use controlled burning (SCHROTH et al., 2004).

A. vulgare fruit has well-defined morphological characteristics with a globular and ellipsoid shape (Figure 2), a diameter of 33.00 ± 2.10 mm, a length of 42.00 ± 2.70 mm, and a total mass of 23.89 ± 0.30 g, as shown in Table 1.

Figure 2 - Tucumã-of-Pará (*Astrocaryum vulgare*) fruit.



Source: The authors (2021)

Table 1 - *Astrocaryum* fruits morphological characteristics

Morphological characteristics	<i>A. vulgare</i>	<i>A. huaimi</i>	<i>A. aculeatum</i>
General description^a	Globose, ellipsoid, and rostrum fruits. Smooth, orange to red epicarp;	Obovoid to subglobose fruits. Smooth, yellow to orange epicarp;	Globose fruits to ellipsoids. Smooth and yellowish epicarp;
Weight (g)	23.89 ± 0.30	16.06 ± 3.52	61.00 ± 15.00
Mesocarp weight (g)	7.80 ± 1.20	5.37 ± 3.52	11.00 ± 4.00
Exocarp weight (g)	5.65 ± 1.00	2.26 ± 0.55	7.00 ± 2.00
Fruit diameter (mm)	33.00 ± 2.10	10.08 ± 0.62	46.00 ± 4.00
Fruit length (mm)	42.00 ± 2.70	27.27 ± 1.86	54.00 ± 4.00
Mesocarp thickness (mm)	3.20 ± 0.60	2.88 ± 0.43	1.80 ± 0.80

Source: Flora do Brasil (2020), adapted.

The epicarp of this fruit has a color that varies from yellow to orange, like the fruits of the species *A. aculeatum* and *A. huaimi*, and therefore, this visual aspect is a possible cause for incorrect identification among the fruits of these three species. In this context, science has modern molecular identification techniques that overcome the limits of visual acuity of the human eye and expand the possibilities of differentiating fruits from two different species. Modern techniques, such as the microsatellite amplification technique with genomic DNA and ribosomal DNA sequencing, are already being applied in scientific works that aimed a more precise taxonomy of fruits belonging to different

species of the genus *Astrocaryum* (OLIVEIRA et al., 2012; OLIVEIRA et al., 2014; RAMOS et al., 2016).

NUTRITIONAL COMPOSITION

The nutritional composition of the *Astrocaryum* genus different species is shown in Table 2, with the tucumã-of-Pará (*A. vulgare*) mesocarp showing the highest percentage of proteins ($8.44 \pm 0.18\%$) and lipids ($58.65 \pm 1.56\%$). The mesocarp of tucumã-of-Pará (*A. vulgare*) fruits, which contains about $58.65 \pm 1.56\%$ of lipids, $8.44 \pm 0.18\%$ of proteins, $7.15 \pm 1.37\%$ of carbohydrates, and $12.02 \pm 0.16\%$ of fiber, is very appreciated by local inhabitants of the Brazilian states of Pará and Manaus (DIDONET and FERRAZ, 2014). Tucumã mesocarp is an important food product that is sold in popular restaurants as a complementary ingredient for the preparation of sweets, sandwiches, and fish-based dishes typical of the Amazon region (KAHN, 2008). In the local market in Manaus, the economic importance of the fruit is so great that its sale value is even higher than the price of apples that are imported into the state (KAHN, 1999).

Table 2 - *Astrocaryum* fruits nutritional composition

Nutritional composition	<i>A. vulgare</i>	<i>A. huaimi</i>	<i>A. aculeatum</i>	<i>A. cham bira</i>	<i>A. murumuru</i>
Moisture (%)	10.62 ± 2.54	10.22 ± 0.25	52.54 ± 3.32	-	24.85
Proteins (%)	8.44 ± 0.18	5.18 ± 0.11	-	3.50	5.25
Lipids (%)	58.65 ± 1.56	18.28 ± 0.04	21.25 ± 1.72	16.60	16.12
Ashes (%)	3.12 ± 0.09	3.58 ± 0.06	1.08 ± 0.05	-	-
Carbohydrate (%)	7.15 ± 1.37	31.46 ± 0.04	-	19.10	-
Fibers (%)	12.02 ± 0.16	35.95 ± 0.01	-	-	-
pH	6.12 ± 0.00	-	5.20 ± 0.02	-	6.08
Acidity (%)	0.16 ± 0.00	-	0.64 ± 0.00	-	0.77
Energy (kcal/100g)	413 ± 2	311 ± 0.00	1232 ± 0.00	247	-
Carbohydrates					
Total pectin (%)	0.71-0.97	-	-	-	-
Soluble Pectin (%)	0.12-0.24	-	-	-	-

Source: Ferreira de Oliveira et al (2018); Santos et al (2017); Santos et al (2018); Azevedo et al (2017) Pereira et al (2006).

In addition to the *A. vulgare* high protein and lipid content, it is also possible to observe the high caloric content of the fruit mesocarp (413 ± 2 kcal/100g); therefore, it is an excellent source of vegetable oil. Regarding carbohydrates, pectin was identified in the tucumã fruit mesocarp in a concentration range that varies from 0.71 to 0.97%. For the food industry, the presence of pectin in tucumã-of-Pará fruit is a huge benefit to produce jams and sweets, as this can reduce the use of commercial pectin (higher cost) and, consequently, reduce the total time of manufacturing (ANTUNES et al., 2006).

There is no doubt that the nutritional richness of the tucumã fruit (*Astrocaryum vulgare*) has left its legacy in history and has brought with it, to the present day, proof of the exotic diversity of Amazonian fruits marked by the aroma, flavor, and texture of the fruit in the local cuisine (DIDONET and FERRAZ, 2014; FERREIRA DE OLIVEIRA et al., 2018).

On the international scenario, the tucumã-of-Pará fruit can be understood as a connector from the Amazon region to the world, either through the direct application of the fruit in gastronomy or for the application of the fruit as an input in the development of functional foods, biodiesel production (ALEXANDRE et al., 2015), production of medicines with preventive action against diseases (BALDISSERA et al., 2017; BONY et al., 2012), sunscreens production (FERREIRA DE OLIVEIRA et al., 2018; MARRONATO et al., 2016), among other applications of interest to the pharmaceutical and food industry.

CHEMICAL COMPOUNDS

Fatty acids

Fatty acid molecules can be classified according to the number of unsaturations, being saturated or unsaturated if there is absence or presence of unsaturations, respectively, in the carbon chain. The benefits of polyunsaturated fatty acids are associated with important metabolic functions in the human body responsible for reducing cellular inflammation, reducing thrombosis, diabetes, and preventing cardiovascular disease (TAHA et al., 2020).

As shown, the tucumã (*A. vulgare*) fruit mesocarp is an excellent source of vegetable oil, whose composition consists mainly of oleic acid (C18:1), according to Table 3. The majority presence of oleic acid (63-75.34% in relation to total fatty acids) confers functional quality for this oil to be used as a substitute for olive oil in an adequate

and controlled diet. Among the saturated fatty acids, palmitic acid (C16:0) is the major component, whose concentration can reach 22.60-26.49% of the oil extracted from the fruit pulp, surpassing the concentration of palmitic acid present in the *A. vulgare* seed (5.3- 6%), in the *A. murumuru* seed (6%), and in the *A. aculeatum* pulp (7.89-8.46%). Benefits associated with palmitic acid include anti-inflammatory effects if given properly in balance with polyunsaturated fatty acids (REBOREDO-RODRÍGUEZ et al., 2016).

Phenolic compounds and Carotenoid composition

Phenolic compounds and carotenoids are molecules produced by plant species and comprise a broad group of chemical compounds with high antioxidant capacity. Phenolic compounds are secondary metabolites constituted of molecules with one or more aromatic rings and can be classified into subgroups known as flavonoids and phenolic acids, among other substances with antioxidant activity (CHEN et al., 2020).

Carotenoids have a high commercial interest, as they comprise bioactive substances that have beneficial effects on human health, regarding the prevention of cardiovascular diseases (HAMMOND and RENZI, 2013; ACHARYA, 2018; RODRIGUEZ-AMAYA and KIMURA, 2004; ABREU et al., 2020).

Santos et al. (2015) carried out a research study with methanolic extracts of Amazonian palm fruits and found that tucumã-of-Pará is a natural source of yellow flavonoids (31 ± 2 mg/100g mesocarp), total anthocyanins (4 ± 0.2 mg/100g mesocarp), and carotenoids (7.2 ± 0.4 mg/100g mesocarp). Anthocyanins are flavonoids and are described as natural antioxidants since they have an ideal structure to inactivate free radicals. According to Santos et al. (2015), tucumã has a high antioxidant capacity (92% Oxidation Inhibition) through the β -carotene/linoleic acid method.

A. vulgare fruits have also been standing out as an important source of carotenoids due to its high number of total carotenoids identified in the edible part of the fruit (122.23 ± 3.45 mg/100g oil) which is greater than the amount identified in the *A. aculeatum* mesocarp (6.265 mg/100g oil) and in the fat of the *A. murumuru* seed (2.18 ± 0.16 mg/100g oil) (ABREU et al., 2020; SANTOS et al., 2015; FALCÃO et al., 2017).

This difference can be explained as a function of the ripening stage of the fruit, collection region, and operating conditions of each extraction procedure that was used by each author to obtain the extract. The detailed carotenoid composition of the oil extracted from the *A. vulgare* fruit is shown in Table 4.

Table 4 - A. vulgare fruit carotenoid composition

Carotenoids	Concentration (mg/kg oil)
Neoxanthin	76.08±6.72
Violaxanthin	13.53±0.57
Luteoxanthin	16.13±0.88
Cis violaxanthin	12.80±0.92
Lutein	44.34±1.44
Cis lutein	12.57±0.12
β-cryptoxanthin	14.43±1.31
5,8 epoxy β-carotene	27.25±2.69
Cis γ carotene	75.87±5.54
γ carotene	68.02±3.44
α-carotene	29.21±2.62
Cis β-carotene	230.92±14.50
β-carotene	567.08±25.29
Total	1222.33±34.50

Source: Santos et al (2015).

The carotenoids profile presented in Table 4 shows the dominance of the β series in tucumã-of-Pará (*A. vulgare*) oil, where a similar qualitative profile is verified in tucumã-of-Amazonas (*A. aculeatum*) oil, mainly regarding the β-carotene dominance (DE ROSSO and MERCADANTE, 2007). This dominance confers quality on tucumã oil to be consumed through the fruit pulp in its fresh form, as it presents an expressive amount of the vitamin A precursor, in addition to representing a concentration of β-carotene ninety times higher than in avocado, supplying required daily doses (FERREIRA DE OLIVEIRA et al., 2018).

Phytosterols

Phytosterols are chemical substances that have a proven biological effect and beneficial to human health in the prevention of cardiovascular diseases, diabetes, and can act to reduce Low-density lipoprotein cholesterol (LDL-C) (GHAEDI et al., 2019; HANNAN et al., 2020). Bony et al. (2012) reported β-sitosterol (488.2±23.8 μg/g) being the phytosterol present in greater quantity in the *A. vulgare* fruit mesocarp, followed by Arundoin (241.9±11.6 μg/g), Cycloartenol (170.3±16.7 μg/g), Campesterol (133.2±4.2 μg/g), and Stigmasterol (66.1±5.0 μg/g). These results showed that the tucumã fruit mesocarp is a good source of phytosterol and can be included in the diet to contribute to the recommended daily intake amount (KEYS et al., 1957).

Methods of extraction

Most studies reported in the scientific literature show wide application of conventional techniques, such as Soxhlet and cold maceration, to extract vegetable oil from the *A. vulgare* fruit, with hexane being the most frequently used solvent, as shown in Table 5. Hexane is usually chosen as the extraction solvent, as its polarity is like the vegetable oil polarity, which provides high extraction yields (MEZZOMO et al., 2009).

Table 5 - *A. vulgare* fruit oil extraction methods

Method of extraction / Solvent	Yield (%)	Reference
Soxhlet / Hexane	-	Pardauil et al. (2017)
Soxhlet / Hexane	29.6	Mambrim and Barrera-Arellano (1997)
Supercritical fluid extraction / Dioxide of Carbon	70.6	
	79.8	Costa et al. (2016)
Soxhlet / Hexane	-	Bony et al. (2012)
-	-	dos Santos et al. (2015)
Soxhlet / Hexane	-	Santos et al. (2017)
Soxhlet / Diethyl ether	-	Santos et al. (2015)
Cold maceration / Chloroform and methanol	31.0	Rodrigues et al. (2010)
	41.8	

However, although Soxhlet and cold maceration techniques provide high extraction yields, these techniques usually require long extraction times and high amounts of organic solvents to ensure solubilization, in addition to leaving a degreased residue that can pose risks to human health and possibility of environmental contamination if the solvent is not properly removed (MEZZOMO et al., 2009; BELWAL et al., 2020).

Modern extraction industries have undergone drastic changes in their economic and environmental policies, mainly due to the demands of international organizations and research groups, which have profound impacts on the environment and society about pollution and the generation of solid and liquid waste. A new perspective, which contributes sustainably to production at an industrial level, has raised many relevant questions about the plant extracts production on a large scale, increased productivity, skilled labor, income generation, sustainable industrial plants, and industrial modernization policies. Thus, current requirements focus on a public that is increasingly

aware of its responsibilities towards the environment and its relationship with sustainable industrial development, in the use of natural products (BAI et al., 2020; FRANK et al., 2019).

In the current context of technological innovations and application of green technologies, supercritical fluid technology is a promising alternative with highly proven economic, social, pharmacological, and environmental potential to be applied to the processing of natural products (BELWAL et al., 2020; KNEZ et al., 2019). Specifically, the technology with supercritical carbon dioxide has shown high efficiency in vegetable oil extraction and high selectivity in obtaining bioactive compounds, such as lutein, anthocyanins, carotenoids, and total polyphenols, in addition to generating vegetable oil and a residue totally free from organic solvent contamination (SILVA et al., 2019; PINTO et al., 2020).

Costa et al. (2016) obtained vegetable oil from *A. vulgare* using 10 kg of sample which was solubilized in supercritical carbon dioxide at a pressure of 300 bar, temperatures ranging between 40°C and 60°C, and with a constant solvent flow of 15 g/min. The extracted oil showed carotenoids, which varied in the range of 2065-2101 ppm, palmitic acid (C16:0), which varied in the range of 22.60-26.49% in relation to the total fatty acids, and oleic acid (C18:1), which ranged from 54.14-71.77% also in relation to total fatty acids, in addition to providing high oil extraction yields (70.6–79.8 g oil/100 g mesocarp).

MAIN BIOLOGICAL ACTIVITIES

This section presents the latest results of detailed research on the pharmacological effect of extracts obtained from fruits and other parts of *Astrocaryum vulgare*. Although there are not many studies on the biological potential and pharmacological activities of *Astrocaryum vulgare*, recent studies have shown that biologically active compounds such as pigments and phenolic compounds are responsible for several biological activities. The findings in the literature show potentials such as reduction of cytotoxic effects, anti-inflammatory activity, redox balance improvement, antioxidant activity, antidiabetic, and antimicrobial activity. All these biological and pharmacological activities are described in the next subtopics.

Cytoprotective activity

Cytotoxicity is a general term used in pharmacological laboratory analyzes, used to describe the effects of chemical substances on cell models. Cytotoxicity tests are important to understand whether a particular substance or set of substances in an extract has properties that are tolerant at the cellular level (STAVROU et al., 2018).

Several techniques use the principles of cytotoxicity to assess the biological potential of plant extracts. Among these models, the use of radicals is common, as is the use of hydrogen peroxide. Hydrogen peroxide is highly reactive and toxic to cells, a small amount of this radical is sufficient to degrade the cell wall, cause damage to DNA, and lead to cell death. Thus, extracts and or even isolated substances that reduce the damage caused by these radicals are especially desirable (ROLEIRA et al., 2015).

The presence of compounds such as rutin, gallic acid, caffeic acid, chlorogenic acid and carotenoids in the tucumã bark, seems to be responsible for inhibiting the action of free radicals. According to the study by Sagrillo et al. (2015), the presence of high levels of β -carotene and quercetin in the pulp and bark of tucumã inhibit degenerative effects caused by H_2O_2 , even in high concentrations of this radical. According to these authors, tucumã extracts activate the caspase pathway in human lymphocytes, thus leading the cell to responses involving modulation of apoptosis. This study is the first in the literature to demonstrate the cytoprotective effects of bark extracts and pulp tucumã, indicating the biological potential and possible applications, such as in the production of anticancer drugs.

Anti-inflammatory activity

Inflammatory diseases and or even inflammatory clinical conditions are common and are always associated with the production of pro-inflammatory substances. Pro-inflammatory chemicals can be enzymes and or other compounds. Each pro-inflammatory substance has a specific purpose and production is controlled by a set of individual genes. We know that the production of inflammatory clinical conditions can occur for several reasons, such as contagion by microorganisms, toxic substances, radiation, and others (MIAO et al., 2019). Although there are several synthetic substances on the market with anti-inflammatory activity such as Aspirin, Ibuprofen, Naproxen, and others, there is a relentless search for new natural compounds with similar or more efficient potential (ACOSTA-ESTRADA et al., 2014).

Plants are a source of biologically active compounds with anti-inflammatory potential, as shown in several recent reports (FIDELIS et al., 2020; HOU et al., 2020; WU et al., 2020). Thus, *Astrocaryum spp* also has the potential to produce anti-inflammatory drugs. According to Bony et al. (2012), the fruits of *Astrocaryum vulgare* M. have important anti-inflammatory activity. The authors show that the presence of fatty acids, tocopherol, carotenoid, and phytosterol in the oil influence the reduction of pro-inflammatory factors. The study conducted in mice showed that the administration of the oil could attenuate the inflammatory process, mainly by reducing pro-inflammatory cytokines. With the inhibition of the pro-inflammatory cytokine production mechanisms, an increase in the production of anti-inflammatory cytokines was evidenced, which reduced the effects caused by endotoxic shock.

Anti-diabetic activity

Diabetes is a disease caused by changes in the metabolism of insulin production and absorption by cells. Insulin is an important hormone responsible for the regulation of glucose present in the blood and has the function of breaking down glucose molecules, releasing energy for cellular activities (LUO et al., 2016). When disturbances in insulin synthesis occur, we have the inhibition of several important biochemical processes, reducing life expectancy. Although modern insulin treatments are effective in replacing the hormone, they do not cure the disease, which ends up becoming chronic (ZHANG et al., 2019). Therefore, disease prevention remains the best way to reduce the risk of clinical complications. In recent years, great effort has been made by researchers in the search for healthy foods with anti-diabetic properties. In this scenario, we believe that further studies with *Astrocaryum spp*, may elucidate aspects not yet understood about the anti-diabetic potential, and may in the future be an effective medication (CARDULLO et al., 2020; WANG et al., 2020).

Treatment with tucumã oil (*Astrocaryum vulgare*), Showed promising effects in reducing blood glucose levels in diabetic mice. Tucumã oil reduced the production of enzymes such as NTPDase (adenosine triphosphate (ATP substrate) and adenosine deaminase (ADA; adenosine substrate). Therefore, tucumã oil can modulate the changes caused by the disease, probably due to the presence of pigments such as carotenoids. Normal levels of ATP, ADP, AMP, and adenosine help activate anti-inflammatory responses, helping the immune system to cope with the side effects of increased blood glucose (BALDISSERA et al., 2017).

According to Baldissera et al. (2017), Tucumã oil has enzymatic antioxidant properties, that is, it reduces the presence of free radicals, acting directly against substances responsible for lipid peroxidation, reducing cell wall degradation and DNA damage. The hypoglycemic effect was observed in studies with diabetic mice induced by alloxan. The presence of a higher concentration of oleic / elaidic fatty acid in the oil, acts as an insulin level inhibitor, in addition to reducing side effects on the pancreas. This research shows that extracts of *Astrocaryum spp* are a viable alternative in the treatment of hyperglycemia.

Antimicrobial activity

The antimicrobial activity associated with biologically active compounds from plants and fruits is very common. Recent studies (FIDELIS et al., 2020; BOEIRA et al., 2020; JESUS et al., 2020; MARTILLANES et al., 2020) shown that although the plants are different, the biological potential is common, mainly associated with metabolites secondary as phenolic compounds. There are not many relevant studies on the antimicrobial potential of *Astrocaryum vulgare* however, in a study by Jobim et al. (2014), the presence of metabolites such as quercetin, rutin, β -carotene, Gallic acid, caffeine, and chlorogenic agents can inhibit the activity of bacteria and fungi. It has been shown that extract rich in quercetin have greater antibacterial potential. While extracts rich in rutin have antifungal activity, especially against *C. albicans*. The authors conclude that antimicrobial activity may be mainly associated with REDOX imbalance.

CONCLUSION

With the adaptation of industrialization in the sustainable economy format, which has modernity's such as robotics and automation in technological processes, there is room to assess the potential of other plant species native to the Amazon region, such as tucumã-do-Pará (*Astrocaryum vulgare* Mart.), and other technologies without harming the native forest of the Amazon region. This review paper showed that the *Astrocaryum vulgare* species has a wealth of bioactive substances that provide nutritional and functional quality and enormous economic potential to the fruit that can be sustainably exploited in gastronomy and in the pharmacological area. Tucumã-of-Pará vegetable oil can be extracted using traditional techniques that use organic solvents and high temperatures. However, extraction mechanisms can also be explored using supercritical fluid

technology, which is considered a green technique and an alternative that overcomes the limitations of traditional techniques, regarding process selectivity and mild extraction temperature conditions.

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