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RELEVANCES OF ETHNOBOTANICAL, CHEMICAL AND BIOTECHNOLOGICAL ASPECTS OF ANDIROBA (*CARAPA SPP.*) AS A SOURCE OF APPLICATIONS IN STRATEGIC SECTORS. REVIEW

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ABSTRACT

Objective: This study sought to synthesize in the form of a literature review three aspects widely studied in relation to andiroba and its impacts on the science and oncology sectors.

Theoretical framework: Because andiroba (*Carapa guianensis* Aubl) is widely used in popular medicine, it has led to the emergence of studies investigating its uses, followed by chemical characterization, and more recently with a biotechnological product, which gives the plant an important role.

Method: A survey of the literature was applied, observing three points, which were ethnobotanical, chemical and biotechnological aspects that together comprise the strategic sectors of andiroba studies.

Results and conclusion: The diversity of molecules already discovered, such as fatty acids and limonoids, which show that this plant is a powerful source of new substances with chemical and biological potential, and also their use for the development of plant biotechnology, which indicates new potential uses for andiroba to generate new materials and products.

Implications of the research: It can be considered that the application of more advanced studies towards the generation of products from andiroba inputs still occurs as a result of the little appreciation of the potential of this species within the industry, especially the pharmaceutical industry.

Originality/value: This study analyzes not only aspects that are commonly discussed about andiroba, which are the botanical aspects of the species, but also the characteristics of the plant.

Keywords: Andiroba, Biodiversity, Biotechnological Potential, Popular Medicine.

RELEVÂNCIAS DOS ASPECTOS ETNOBOTÂNICOS, QUÍMICOS E BIOTECNOLÓGICOS DA ANDIROBA (CARAPA SPP.) COMO FONTE DE APLICAÇÕES EM SETORES ESTRATÉGICOS. ANÁLISE

RESUMO

Objetivo: Este estudo buscou sintetizar na forma de uma revisão da literatura três aspectos muito estudados em relação a andiroba e seus impactos sobre setores de geração de ciência e téncologia.

Estrutura teórica: A andiroba (*Carapa guianensis* Aubl) por possuir um amplo emprego de uso popular, provocou o surgimento de estudos que a priori investigaram sua relação de usos, seguida de caracterização quimica e mais atualmente com um produto biotecnológico, o que confere a planta um papel de destaque.

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Método: Aplicou-se um levatamento da literatura observando três pontos, que foram aspectos etnobotânicos, químicos e biotecnológicos que juntos compõe os setorer estratégicos de estudos da andiroba.

Resultados e conclusão: A diversidade de moléculas já descobertas, como os ácidos graxos e limonóides, e que evidenciam que esta planta é uma poderosa fonte de substâncias novas com potencial químico e biológico e, ainda seus empregos para o desenvolvimento da biotecnologia vegetal, o que indica novos potenciais de uso para a andiroba no sentido de gerar novos materiais e produtos.

Implicações da pesquisa: Pode-se considerar que a aplicação de estudos mais avançados no sentido de geração de produtos a partir de insumos da andiroba ainda ocorre em consequência da pouca valorização do potencial dessa espécie dentro da indústria, principalmente a farmacêutica.

Originalidade/valor: Este estudo analisa não somente aspectos que comumente são discutidos da andiroba, que são os aspectos botânicos e etnobotânicos, mas as descobertas em química e como isso implica na biotecnológia, e que torna uma fonte riquíssima de desenvolvimento de novas tecnologias.

Palavras-chave: Andiroba, Biodiversidade, Potencial Biotecnológico, Medicina Popular.

1 INTRODUÇÃO

The andirobeira belongs to the genus Carapa of the Meliaceae family, popularly known as andiroba is considered a large plant occurring throughout the Amazon basin, Central America and Africa of occurrence predomeinante in floodplain environment (SHANLEY, 2005; COSTA, 2013; SALGADO, 2015). The wood is highly appreciated for the production of furniture and construction, the oil is used by the industry for the production of soaps, creams, ointments and candles of repellent character, and is also used in folk medicine as a powerful healing and anti-inflammatory agent (FERRAZ, CAMARGO, SAMPAIO, 2003; BERG, 2010).

Andiroba has gained prominence in science due to its medicinal properties being verified through chemical, pharmacological and biological studies, which over the years have generated even more publications. Therefore, the goal of this study was to conduct a literature review, exposing the ethnobotanical, chemical, and biotechnological aspects of andiroba (*Carapa spp*.), in order to enhance the potential applications of andiroba in society and its importance for biodiversity. As well as contribute to publications that point to the appreciation of this species for sustainable development and environmental preservation.

2 METODOLOGY

This review consisted of a survey of publications, on the research platforms of journals available on the web, that were related to ethnobotanical studies, chemical characterization and biotechnological applications. A criterion was also established for the selection of publications that were within the objectives of this study, from 2010 to 2023. Thus, this review was divided into three topics: ethnobotanical aspects, chemical aspects and biotechnological aspects.

3 RESULTS AND DISCUSSION

In Brazil there is a vast diversity of names used to refer to the andiroba tree, and among the many, the best known are aborida, aldirova; andiroba; andiroba-aruda; andiroba-branca; andiroba-do-igapó; andiroba-lisa; andiboba-sauda; andirova; angirova; carapá; carapinha, camaçari; caropá; comaçari; gendiroba; saruda; camaçari; carapá; carapinha; caropá; genidiroba; landirova; mandiroba; nandirova; penaíba; purga-de-santo-antônio and purga-de-santo-inácio (RIBEIRO et al. , 2021).

When an overview of the medicinal uses of andiroba is performed, numerous applications are observed where all parts of the plant are used and employed for the treatment of diseases (RIBEIRO et al., 2021, BONES et al., 2022; MOURA et al., 2023). Studies in ethnobotany reveal that the andirobeira is a versatile plant, because the oil extracted from the seeds is used for the treatment of inflammation from injuries as well as chronic, anti-inflammatory, cicatricial, antiviral, antibacterial, antifungal, anit-helminthic and even in the treatment of coronavirus (BRITO et al., 2020; BARROS, 2021). Such uses are described in Table 1.

Table 1: Uses of andiroba found in some literature.

Uses	Plant part used or input	Forma de uso	Literatura
Anti-inflammatory	Crude oil	Oil	(Brito *et al.*, 2019; Coelho *et al.*, 2018)
Healing	Crude oil	Oil	(Brito *et al.*, 2019; Coelho *et al.*, 2018; Sousa *et al.*, 2021; Sousa *et al.*, 2019)
Antiviral	Crude oil	Oil, syrup	(Coelho *et al.*, 2018; Mafra, Lasmar & Rivas, 2020; Barros, 2021; Nardi *et al.*, 2016)
Antifungal	Crude oil	Oil	(Brito *et al.*, 2019)
Anti-helminthic	Crude oil	Oil	(Fernandes *et al.*, 2016; Carvalho *et al.*, 2012; Machado & Mendes, 2021)
Bactericide	Crude oil	Oil	Nonato *et al* (2018)
Acaricide	Crude oil	Oil	Nonato *et al* (2018)
Carrapaticide	Crude oil	Oil	Nonato *et al* (2018)
Anti-tumor	Crude oil	Oil	(Machado & Mendes, 2021)
Antiallergic	Bark of the trunk	Tea, cleansing bath	(Coelho *et al.*, 2018)

Fonte: Barros (2021), Brito *et al*., (2019), Carvalho *et al.* (2012), Coelho *et al.* (2018), Fernandes *et al.* (2016) Sousa *et al.* (2019), Sousa *et al.* (2021), Coelho *et al.* (2018), Machado & Mendes, (2021), Mafra, Lasmar & Rivas, (2020), Nardi *et al.* (2016).

The vast majority of studies conducted in ethnobotany the healing effect is one of the most cited by respondents, and most prominently the oil, which appears among the most cited forms of use (RIBEIRO et al., 2021; SOUSA et al., 2019).

When investigating the dermatological applications of the oil, the number of uses becomes even more comprehensive, going beyond the treatment of simple wounds, as well as scabies, dermatophytes, pityriasis versicolor, pruritus and all other skin lesions, in vivo scarring analysis and mucositis and fibroblast activation (CELA et al, 2012; NAYAK et al 2010; SILVA et al, 2015; SOARES et al, 2021; SILVA et al, 2021; MELO et al, 2021; SANCHES et al, 2021).

Research on the chemical profile of andiroba oil shows that palmitic and oleic acids are the substances observed in higher concentrations, followed by stearic, linoleic, linolenic and myristic acids (SALGADO et al., 2015; FARIAS; FILHO & CHAVES, 2013; SARAIVA et

al., 2009). Table 2 shows the data of the composition of fatty acids present in the oil of *Carapa guianensis*.

Table 2: Fatty acid profile according to the literature.

Fatty Acids	N.C.	% A	% B	% C
Myristic	C14:0	0,52	0,13	0,06
Palmitic	C16:0	26,78	28,29	26,81
Palmitoleic	C16:1	-	-	0,44
Oleic	C18:1	32,56	49,74	54,56
Stearic	C18:0	2,89	8,57	7,72
Linoleic	C18:2	2,14	7,57	8,09
Linolenic	C18:3	-	1,49	0,19
Arachidic	C20:0	0,93	-	1,12
Beenico	C22:0	-	-	0,16

Source: SALGADO et al. (2015), FARIAS; FILHO & CHAVES (2013); SARAIVA et al., (2009). **N. C**.: Number of carbons.

The tetranortriterpenoids most commonly found in C. guianensis oil by virtue of their higher concentration reported in the literature are limonoids (figure 1), being gedunin, 6α-acetoxygedunin, methyl angolensate 7-desacetoxy-7-oxogedunin, andirobin, methyl 6-hydroxyangolensate, 17β-hydroxyazadiradione, 1,2-dihydro-3β-hydroxy-7-desacetoxy-7-oxogedunin, and xyloccensin k (AMBROZIN et al., 2006; TAPPIN et al. 2008; SILVA et al., 2009).

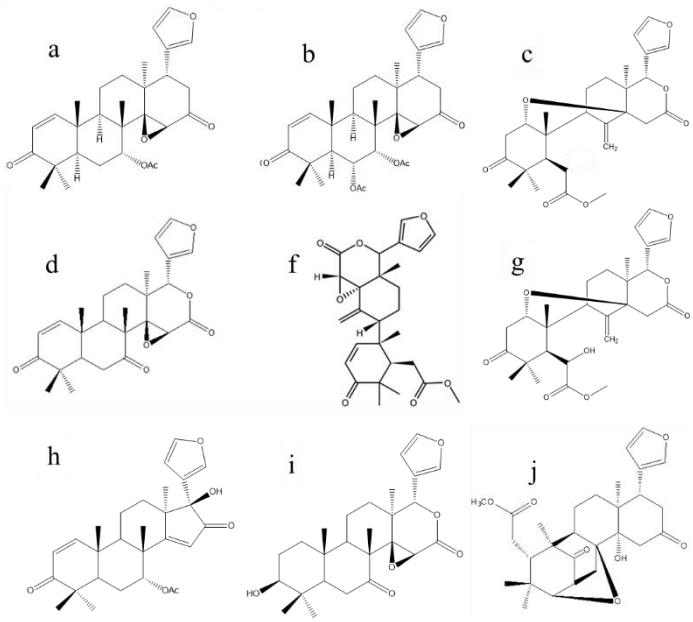

Figure 1: Some of the main limonoids found in *C. guianensis*. (a) gedunin,(b) 6α-acetoxygedunin, (c) methyl angolensate, (d) 7-desacetoxy-7-oxogedunin, (f)andirobin, (g) methyl 6-hydroxyangolensate, (h) 17β-hydroxyazadiradione, (i)1,2- dihydro- 3β-hydroxy-7-desacetoxy-7-oxogedunin, (j) xyloccensin k.
Fonte: Ambrozin *et al*. (2006), Tappin *et al*. (2008), Silva *et al*. (2012).

Besides these limonoids in the literature are reported the isolation of other tetranortriterpenoids called carapanolides (fig. 2) from the oil of andiroba seeds (INOUE et al., 2012; 2014; 2015).

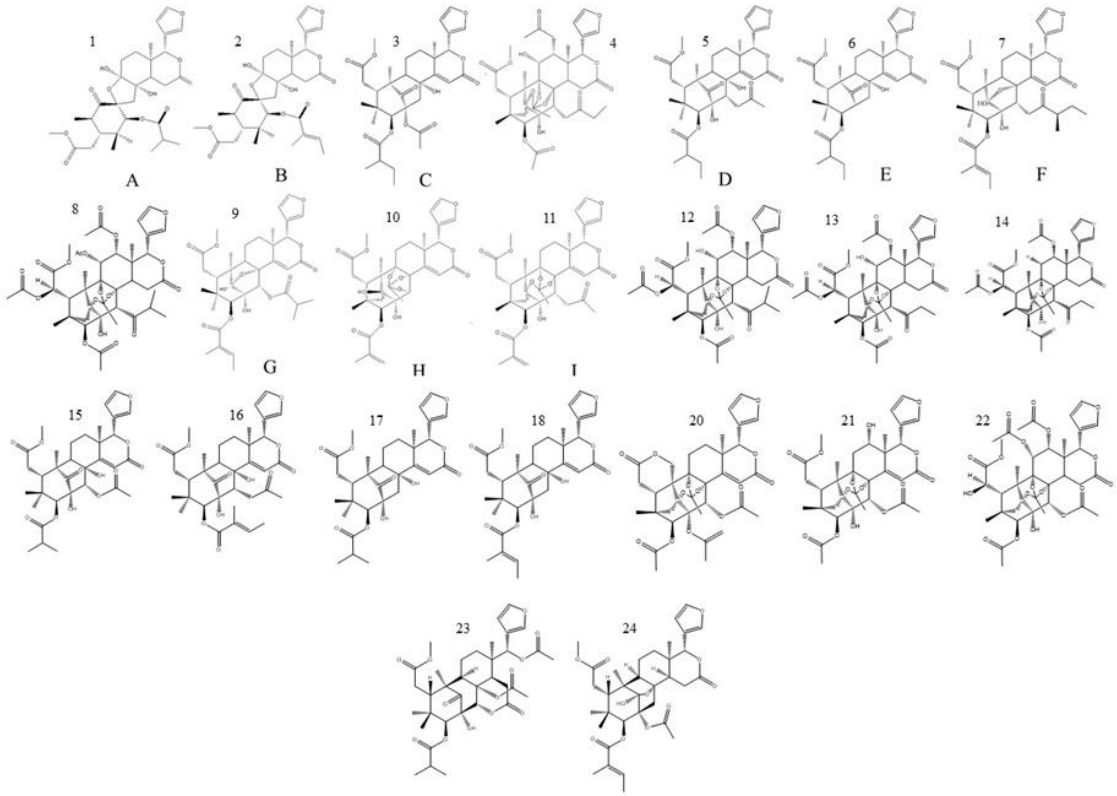

Figure 2: Carapanolides isolated from the oil of *Carapa guianensis* Abul. Seeds
Source: Inoue *et al*. (2012, 2014, 2015), Miyake *et al*. (2015).

Over the past decade studies have revealed new limonoid structures isolated from andiroba oil and flowers, totaling a number of 25 new molecules described and classified as andirolides. (TANAKA et al., 2011; TANAKA et al., 2012; SAKAMOTO et al., 2013; SAKAMOTO et al., 2015). The structures of the 25 limonoids titled as andirolides are described in Figure 3.

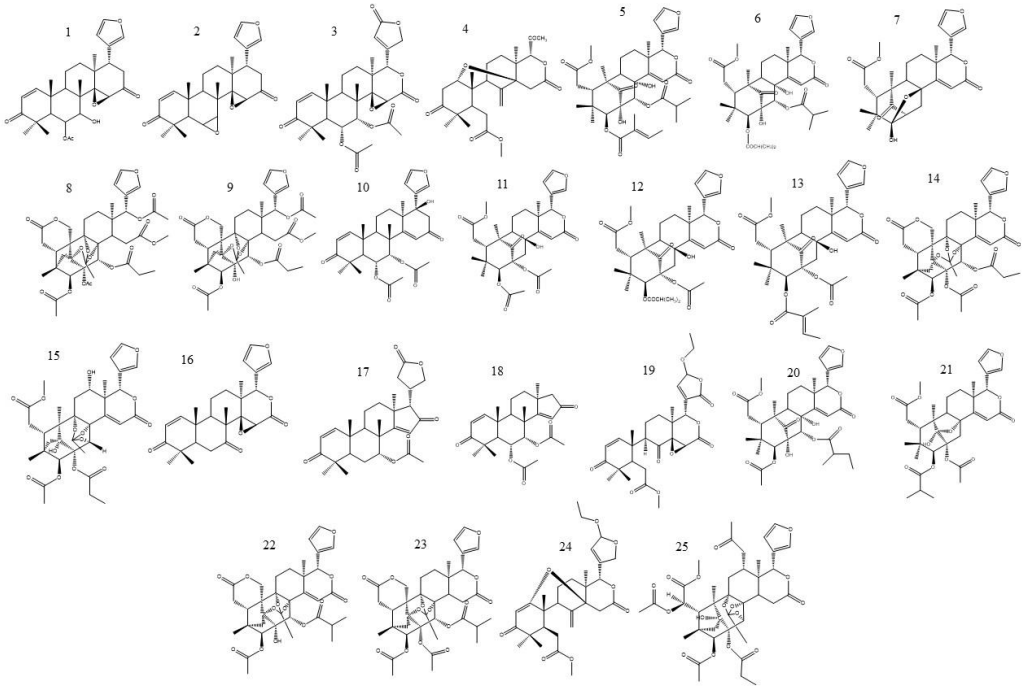

Figure 3: Chemical structure of andirolide-type limonoids isolated and described in the literature.
Source: Tanaka *et al*. (2011, 2012), Sakamoto *et al*. (2013, 2015).

Three new limonoids isolated from the oil of the andiroba fruit were obtained in 2020, classified as carapanins, the research showed that these molecules do not possess cytotoxicity, so it is possible that they have pharmacological potential (KIKUCHI et al., 2020). The structures of these limonoids are shown in Figure 4.

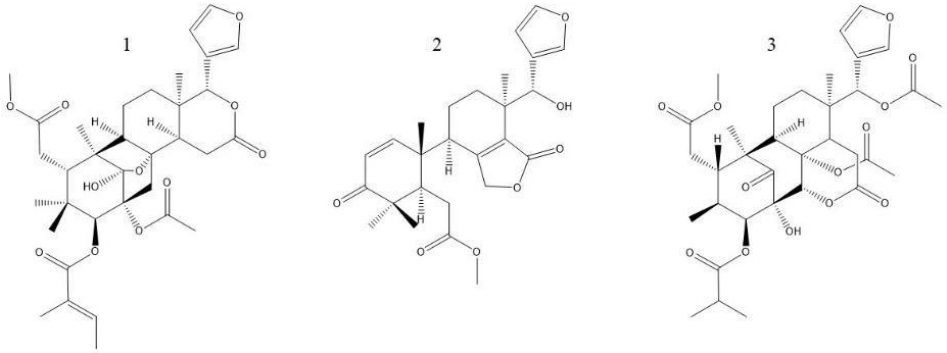

Figure 4: Carapanins isolated from the oil of *Carapa guianensis* Abul. seeds.
Source: Kikuchi *et al*. (2020).

Between 2017 and 2018 a number of six new limonoids were discovered and their structures were published and classified as carapanosins, in addition to chemical structural characterization, biologic assays were performed and revealed the macrophage inactivation potential of these molecules (HIGUCHI *et al*, 2017; INOUE *et al*., 2018). The structures of these limonoids are shown in Figure 5.

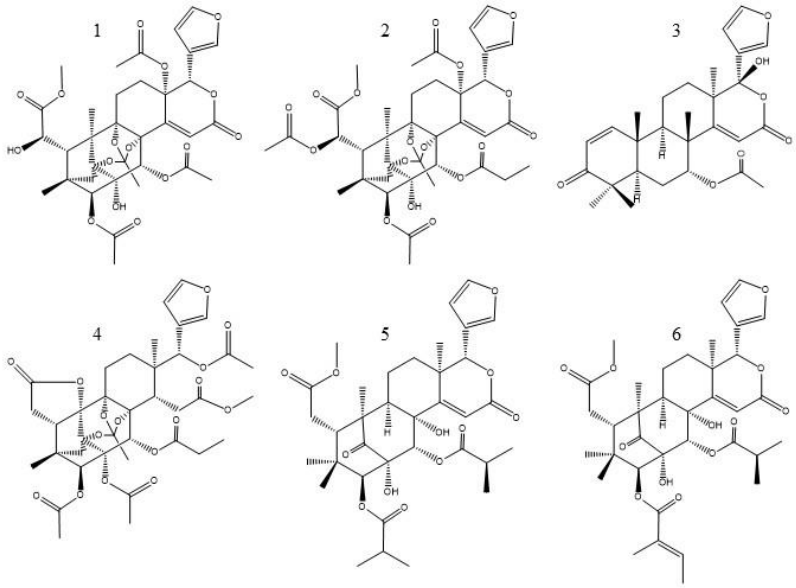

Figure 5: Carapanosins isolated from the oil of *Carapa guianensis* Abul. seeds.
Source: Higchi *et al*. (2017), Inoue *et al*. (2018).

Seven novel limonoids (fig. 6) were described in 2019 and classified as guianofruits, these new molecules add to the other tetranortriterpenoids already isolated from *Carapa spp* and, an in vivo analysis proved the macrophage inhibition potentials of these molecules (TSUKAMOTO *et al*., 2019).

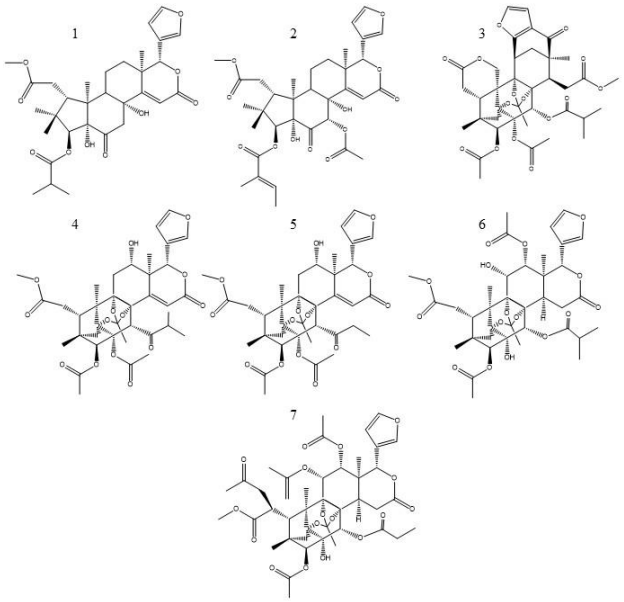

Figure 6: Guianofruits isolated from the oil of *Carapa guianensis* Abul. Seeds.
Source: Tsukamote *et al*. (2019).

Such substances present in *C. guianensis* species in virtually all parts of the plant, having been isolated and identified mainly in the seeds and andiroba oil, however other studies prove large varieties in flowers, bark and leaves (INOUE *et al*. 2012; SAKAMOTO *et al.*, 2013; BATAGLION *et al*., 2014).

Among the available publications related to andiroba (*Carapa guianensis* Aubl.) on the main search platforms for scientific journals, a total of 36 studies were found that involve applications of andiroba through plant biotechnology between the years 2011 and 2022.

The gedunin and other tetranortriterpenoids isolated from andiroba were used in studies investigating the inhibition of the inflammatory process, the data obtained from in silico and in vivo analysis, and revealed that these tetranortriterpenoids have the ability to inhibit proteins that promote the inflammatory process thus characterizing the immunomodulatory potential of these substances isolated from the plant (FERRARIS et al, 2011; FERRARIS et al., 2012; CARMONA et al., 2013; BORGES et al., 2016; CARVALHO et al., 2019).

Regarding antioxidant activity, the main product of andiroba studied is the oil from the seeds, where studies have compraised the antioxidant capacity of the oil, which gives it a potential use by the food and pharmaceutical industries (NOVELLO et al., 2015; ARAUJO-LIMA et al., 2018).

In the search conducted in the literature, 5 publications were found in the last 10 years that focused on investigating the healing activity of andiroba oil. The results found in these studies show the positive effects of andiroba oil on oral mucositis in children affected by leukemia, wound healing in rats from incisions, application of the oil in the form of a micro film that promotes wound healing and in the synthesis of dermal collagen with the use of limonoids from the oil (NAYAK et al., 2011; SILVA et al., 2015; MORIKAWA et al., 2018; SOARES et al., 2020; SILVA et al., 2021).

Promising results have been found in the literature with the oil, employed in the formulations of emulsions and nanoemulsions, thus contributing to the treatment of other diseases caused by cancer, parasites and protozoa (FERREIRA et al., 2010; CELA et al., 2014; JESUS et al., 2017; MORAES et al., 2018; MELO et al., 2021).

Results have been found regarding the antimicrobial activity of andiroba bark, as an antimutagenic agent, positive achievements on insulin resistance, and fatty acid amides synthesized from andiroba oil showed excellent activity as anticonvulsant in the treatment of epilepsy, as well as the oil showed cytotoxicity in stomach cancer cells (SILVA et al., 2014; LEMES et al., 2017; MATSUMOTO et al., 2019; OLIVEIRA et al., 2020; PORFIRIO-DIAS et al., 2020).

Regarding the action as repellent two studies reported their satisfactory results about the repellent action of the oil on Aedes aegypti mosquitoes and flies, other two studies point efficient results against tick species, which gives the oil a carrapaticidal, anthelmintic and antiprotozoal effect (ROMA et al, 2013; ROMA et al., 2015; FERNANDES et al., 2016; SILVA et al., 2020; JESUS et al., 2017; SARQUIS et al., 2020; CARVALHO et al., 2012; OLIVEIRA et al., 2018; AMORIM et al., 2020).

Microparticles of a biodegradable polymer were developed with the purpose of absorbing the andiroba oil without degradation of the chemical and biological properties of the oil, thus making it an ecological alternative for the control of agricultural and urban pests (SENHORINI et al., 2012). The oil has also been employed in the production of biodiesel, polyurethanes, repellent candles and source of phenolic acids (IHA et al., 2014; SILVA; CARDOSO & PETZHOLD; FONTENELLES et al., 2018; SANTOS et al., 2021).

4 FINAL CONSIDERATIONS

By analyzing the ethnobotanical, chemical, and biotechnological aspects, it is possible to see the wide range of applications of the raw materials obtained from andiroba and its potential for developing new materials and drugs. In ethnobotanical aspects the highlight is the variety of uses by the population and how these uses can influence the

development of new research. The chemical aspects include the diversity of tetranortriterpenoids that still need to be investigated regarding their biological activity. Finally, the biotechnological aspects reveal the versatility of andiroba in becoming raw material for the development of new materials and products. All these points lead to the consideration of this plant as a vertex of science and knowledge, being of utmost importance the continuation of new investigations and the preservation of this plant in the Amazon biodiversity.

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