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SUSTAINABILITY ASPECTS OF *CARAPA GUIANENSIS* AUBL OIL FOR ANTIINFLAMMATORY USES

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ABSTRACT

Objective: The objective of this study is to describe the lipidomic profile of andiroba oil and its socio-economic characteristics focused on the activities of limonoids as an alternative for the generation of nonsteroidal anti-inflammatory drugs in order to relate the generation of products that act on circular and external peripheral inflammation.

Theoretical Reference: In this context, andiroba oil (*C. guianensis*) has a wealth of lipid substances with chemical and socio-economic potential, highlighting its importance for local populations and its potential for sustainable bioeconomics, as this species contains nonsteroidal antiinflammatory drugs from Amazonian oil plants.

Method: The methodology adopted includes describing the lipidomic profile of andiroba oil analyzed by GC/MS, using a Zebrom 5HT capillary column specifically designed to analyze both the methyl esters of the various fatty acids and the limonoids and steroids. The bibliographic search was carried out in the CAPES periodicals on the Scopus database, using specific keywords such as andiroba, Carapa, limonoids and antiinflammatories. Three samples of andiroba oil collected in different states were used to compare the lipidomic profiles.

Results and Discussion: The results obtained revealed the presence of limonoids 7-desacetyl-7-oxogedunin, 7-oxogedunin, deacetyl gedunin; steroids campesterol, stigmasterol, b-sitosterol and various medium and long chain fatty acids. These results showed valuable information about the presence of limonoids, which have anti-inflammatory properties related to the chemical composition, which can vary with the season, the place of collection and the differences in the extraction processes of this oil. However, there is no total absence of limonoids.

Research Implications: This research's practical and theoretical implications emphasize that the active anti-inflammatory principles are found in the unsaponifiable fraction, and therefore, only lipidomic techniques can access these metabolites with more excellent resolution. Thus, with the structural identifications, in silico studies can be carried out to classify their effects on cyclooxygenase enzymes (COXs), specifically COX-1, in circular and external peripheral inflammation.

Originality/Value: This study contributes to the literature through the perspective of developing safe anti-inflammatory agents produced from andiroba oil, which is a source of great interest for topical use. This oil stands out as one of the most scientifically studied natural products, being biocompatible and presenting itself as an

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economical and safe alternative for treating circular and external peripheral inflammations. The relevance and value of this research is evidenced by the fact that limonoids are inhibitors of cyclooxygenases, highlighting the prospect of a new socio-economic aspect.

Keywords: Limonoids, Cyclooxygenases, Meliaceae, Lipidomics applied to andiroba oil, Peripheral circular inflammation.

ASPECTOS DE SUSTENTABILIDADE DO ÓLEO DE *CARAPA GUIANENSIS* AUBL PARA USOS ANTI-INFLAMATÓRIOS

RESUMO

Objetivo: O objetivo deste estudo é descrever o perfil lipidômico do óleo de andiroba e suas características socioeconômicas voltadas para as atividades dos limonoides como uma alternativa de gerçaõ de anti-inflamatórios não esteroidais com o intuito de relacionar a geração de produtos que atuem em inflamações perifiercas circular e externas.

Referencial Teórico: Neste contexto o óleo de andiroba (*C. guianensis*) apresenta uma riqueza de substâncias lipídicas com potenciais químico e socioeconômico, destacando sua importância para as populações locais e seu potencial para a bioeconomia sustentável, devido esta espécie conter antiinflamatórios não esteroidais oriundos de planta oleaginosa amazônica.

Método: A metodologia adotada compreende a descrição do perfil lipidômico do óleo de andiroba analisado por GC/MS, utilizando-se coluna capilar Zebrom 5HT especifica para analisar, tanto os esteres metílicos dos diversos ácidos graxo, quanto os limonóides e esteroides. A busca bibliográfico foi realizada nos priodicos Capes na base *Scopus*, utilizando-se palavras chaves especificas tais como andiroba, Carapa, limonoides e anti-inflamatórios. Foram usada três amostra de óleo de andiroba coletadas em Estados diferentes para realizar as comparações dos perfis lipidômicos.

Resultados e Discussão: Os resultados obtidos revelaram as presenças de limonóides 7-desacetil-7-oxogedunina, 7-oxogedunina, desacetil gedunina; esteróides campesterol, estigmasterol, beta-sitosterol e diveros ácidos graxos de cadeias médias e longas. Estes resultados mostraram informações valiosas sobre as presenças dos limonóides que atuam com propriedades anti-inflamatórias, relacionados à composição química que pode variar com a sazonalidade, com o local de coleta e com as diferenças nos processos de extração deste óleo, mas não há ausência total dos limonóides.

Implicações da Pesquisa: As implicações práticas e teóricas desta pesquisa ressaltam que os princípios ativos antiinflamatórios se encontram na fração insaponificável, e portanto, somente as técnicas de lipidômica acessa estes metabólitos com maior resolução. Deste modo, com as identificações estruturais, pode-se realizar estudos *in silico* para classificar seus efeitos sobre as enzimas ciclooxigenases (COXs), especificamente a COX-1 em inflamações periféricas circular e externas.

Originalidade/Valor: Este estudo contribui para a literatura através da perspectiva do desenvolvimento de agentes anti-inflamatórios seguros produzidos a partir de óleo de andiroba, o qual é uma fonte de grande interesse para uso tópico, destacando-se como um dos produtos naturais mais estudados cientificamente, sendo biocompatível e que se apresenta como uma alternativa econômica e segura para o tratamento de inflamações periféricas circular e externas. A relevância e o valor desta pesquisa são evidenciados pelos limonoides serem inibidores das ciclooxigenases ressaltando sua perspectiva de nova vertente socioeconômica.

Palavras-chave: Limonóides, Ciclo-oxigenases, Meliaceae, Lipidômica aplicada ao óleo de andiroba, Inflamação circular perifiérica.

ASPECTOS DE SUSTENTABILIDAD DEL ACEITE DE CARAPA GUIANENSIS AUBL PARA USOS ANTIINFLAMATORIOS

RESUMEN

Objetivo: Describir el perfil lipídico del aceite de andiroba y sus características socioeconómicas orientadas hacia las actividades de los limonoides como una alternativa de generación de antiinflamatorios no esteroideos para relacionar la generación de productos que actúan sobre inflamaciones circulares y externas periféricas.

Referencia Teórica: En este contexto, el aceite de andiroba (C. guianensis) presenta una riqueza de sustancias lipídicas con potencial químico y socioeconómico, destacando su importancia para las poblaciones locales y su potencial para la bioeconomía sustentable, debido a que esta especie contiene productos antiinflamatorios no esteroideos originarios de la planta oleaginosa amazónica.

Método: La metodología adoptada comprende la descripción del perfil lipídico del aceite de andiroba analizado por GC/MS, utilizando la columna capilar Zebrom 5HT específica para analizar tanto los ésteres metílicos de los diversos ácidos grasos, como los limonoides y esteroides. La búsqueda bibliográfica se realizó en las publicaciones periódicas Capes de la base Scopus, utilizando palabras clave específicas como andiroba, Carapa, limonoids y antiinflamatorios. Se compararon los perfiles lipídicos de tres muestras de aceite de andiroba recolectadas en diferentes estados.

Resultados y Discusión: Los resultados obtenidos revelaron la presencia de limonoides 7-desacetil-7-oxogedunina, 7-oxogedunina, desacetil gedunina; esteroides campesterol, estigmasterol, beta-sitosterol y diversos ácidos grasos de cadenas medias y largas. Estos resultados mostraron información valiosa sobre la presencia de limonoides que actúan con propiedades antiinflamatorias, relacionadas con la composición química que puede variar con la estacionalidad, con el lugar de recolección y con las diferencias en los procesos de extracción de este aceite, pero no hay ausencia total de limonoides.

Implicaciones de la investigación: Las implicaciones prácticas y teóricas de esta investigación destacan que los principios activos antiinflamatorios se encuentran en la fracción insaponificable, y por lo tanto, solo las técnicas de lipidomía acceden a estos metabolitos con mayor resolución. Así, con identificaciones estructurales, se pueden realizar estudios in silico para clasificar sus efectos sobre las enzimas ciclooxigenasas (COXs), específicamente COX-1 en inflamaciones circulares y periféricas externas.

Originalidad/Valor: Este estudio aporta a la literatura a través de la perspectiva del desarrollo de agentes antiinflamatorios seguros producidos a partir del aceite de andiroba, el cual es fuente de gran interés para el uso tópico, destacándose como uno de los productos naturales más estudiados científicamente, siendo biocompatibles y presentándose como una alternativa económica y segura para el tratamiento de inflamaciones circulares y externas periféricas. La relevancia y el valor de esta investigación se evidencian en que los limonoides son inhibidores de las ciclooxigenasas, enfatizando su perspectiva de una nueva vertiente socioeconómica.

Palabras clave: Limonoides, Ciclooxigenasas, Meliáceas, Lipidomía Aplicada al Aceite de andiroba, Inflamación Periférica Circular.

1 INTRODUCTION

This paper describes the importance of andiroba oil, specifically the species *C. guianensi and C. procera* in the Amazon bioeconomy and the role of riverside communities in sustainably using forest resources. The analysis of andiroba oil shows the richness of lipid compounds and describes the chemical composition of andiroba oil and its variations.

In this study, the extraction of non-timber products, such as andiroba oil, stands out because it has little or no environmental impact and highlights forest functionality, making it an economically viable practice and one of the most effective ways of preserving the forest. The aim is to provide new information on the use of to promote initiatives with greateroil in peripheral inflammatory applications and initiatives with greater and more significant scientific backing within the andiroba production chain.

Notably, andiroba oil is a natural source of fatty acids linked by esterification to form acylglycerols. The oil's lipid composition is predominantly comprised of oleic, palmitic, stearic and linoleic acids bound to glycerol, accounting for approximately 96 to 98% of its total lipids. In comparison, the remaining 2 to 4% consists of unsaponifiable material, which includes saponins, limonoids, steroids and other lipids.

This work aims to deepen the theory of the use of andiroba oil on various inflammations based on the metabolic profile determined through GC/MS analysis for new economic perspectives. The study focuses on lipidomics, highlighting limonoids and the oil's potential for COX-1 inhibition, thus directing the investigation towards an alternative approach with prospects for application in circular peripheral anti-inflammatory uses and towards a socio-economic view.

2 THEORETICAL FRAMEWORK

The Amazon rainforest, an essential source of natural resources, has been severely impacted by human activities, particularly by the unsustainable exploitation of inputs as raw materials for commercial and industrial purposes. One example is the andirobe tree species, which belong to the Meliaceae family and are distributed in the Carapa genus (Cui et al., 2023), (Conab, 2017). When located in the floodplain forests of the Amazon estuary, these species are relevant to riverine and non-riverine peoples, fishermen, small farmers, Indians and various groups of Amazonian population, including those in the metropolitan region. These species were used for three different purposes until two decades ago: the first was oil extraction, the second was timber extraction and the third was the use of bark, heartwood and flowers in folk medicine (Ferraz, Camargo, & Sampaio, 2002), (Busman, 2016). At the moment, Amazonian people have changed their behavior and are working in new directions with four different objectives. The first is the extraction of oil; the second is the collection of seeds, the third is the preservation of the andiroba tree and the fourth is the search for new perspectives for bioeconomy and sustainability.

Within this vision, the extraction of non-timber products, which have little or no environmental impact, and forestry functionality, an economically viable practice, are presented as practical means of maintaining harmony in the rainforest. (Nardi-Santos, 2013). The most significant observation is that local populations in the Amazon are driving initiatives to develop agro-industrial production chains (Christenhusz & Byng, 2016), often in collaboration with governmental and non-governmental institutions (Martiniano, Machado Junior, Silva, & Silva, 2023). In this case, it is seeking to develop green pharmacy models, specifically in the production of soaps, candles, creams, and lotions and, specifically, in the fractionation of andiroba oil and bark tincture, as well as in the collection and germination of seeds to generate seedlings, as this plant has great potential as a medicinal plant (Chia et al., 2018).

Historically, herbal medicines have played an essential role in medical care, with extensive use documented in pharmacopeias until the 19th century (Cook, 1946). In particular, medicinal plants remain vital sources of medicine, even with the significant advances in medicine since the mid-twentieth century. Plants have become crucial for identifying chemical compounds that can fight disease, as highlighted by (Leandro, Jardim, & Gavilanes, 2017). In the Amazon, a diverse range of plant species has been used as a source of medicines, with andirobeiras (Carapa spp) being notable examples, noting that the genus Carapa, belonging to the Meliaceae is taxonomically classified under the order Sapindales, class Magnoliopsida, phylum Tracheophyta and kingdom Plantae, as described by (Santos et al., 2020).

According to the World Health Organization, medicinal plants are widely used by most people in developing countries for their health needs (Lima Melro et al., 2020). However, this source of medicine has been widely used and/or studied by several developed and developing countries, including:

1. India	7. Italy	13. South Korea	19. Canada
2. United States	8. United Kingdom	14. Saudi Arabia	20. Japan
3. Brazil	9. Germany	15. Australia	21. Indonesia
4. Iran	10. Nigeria	16. Mexico	22. Russia
5. Pakistan	11. Malaysia	17. Turkey	23. Taiwan
6. South Africa	12. Spain	18. France	

This list, based on the number of documents analyzed through the Scopus database, highlights the global interest and research efforts around medicinal plants, which are important resources that provide a variety of non-timber forest products (NTFPs), which are sources of food, pharmaceuticals, nutraceuticals, insecticides and repellents, perfumery and cosmetics. One of these NTFPs is andiroba oil, which has a high frequency of commercially valuable products.

A recent study on the lipid profile of andiroba oil in Pará and Amazonas states identified five distinct metabolites: limonoids, acylglycerides, free fatty acids, steroids and phospholipids (Reis & Santos, 2021). In addition, carotenoids and traces of hydrocarbons can occasionally be detected.

Several ethnopharmacological studies have been used as a basis for scientific investigations and application of andiroba oil, including its repellent and larvicidal properties, insecticides (Miranda Júnior, Dolabela, Da Silva, Póvoa, & Maia, 2012) carrapaticidal, anthelmintic, healing and antiinflammatory properties (Araujo- lima et al., 2018). In this context, for the first time, we are investigating the bioeconomic potential related to the antiinflammatory activity of limonoids, a type of tetranortriterpenoid found in andiroba oil, which can inhibit cyclooxygenases 1 and 2. Notably, andiroba oil is preferred for topical use, and COX-1 inhibition is a crucial research target, as it could lead to the development of therapeutic agents with improved safety profiles. COX-1, like COX-2, also promotes the production of thromboxane A2, which is a pro-aggregate substance, acting on platelet aggregation, controlled, has relevant importance for life, and is part of the first stage of the hemostasis process, controlling hemorrhagic processes (Budsberg, 2009).

Blocking mainly COX 1 in platelets and the vascular endothelium promotes the reduction of thromboxane A2, reducing the thrombogenic effect (Armstrong et al., 2011). During this action, COX-2 present in the endothelium, if it is not inhibited or if it is little inhibited, will continue to produce PGI2, which is an anti-aggregant substance, extending this effect, similar to the effect caused by acetylsalicylic acid (Costa-Tort et al., 2021). Thus, it can be inferred that the action of the limonoids present in andiroba oil has the potential to inhibit COX-1.

Selective or highly potent COX-1 inhibitors (Cingolani et al., 2017)have the potential to create more effective or targeted treatments for various diseases, including peripheral circulation disorders such as phlebitis. Phlebitis usually occurs in superficial veins close to the skin, usually in the arms and legs, and is commonly associated with inflammation of the veins and arteries. Andiroba oil has a wide range of traditional uses, including treating muscle contusions, dislocations, tendonitis, dermatitis and sprains. It also relieves symptoms associated with fever, malaria, parasitic infections, insect bites, arthritis, rheumatism and pain (Leandro et al., 2017).

3 METHODOLOGY

3.1 OBTAINING THE MOLECULES TO BE ANALYZED

The metabolic concentrate rich in limonoids was obtained from the oil of C. guianensis seeds. The Andirobeiras (C guianensis) seeds were sent from INPA (National Institute for Amazonian Research) Adolph Ducke Park Reserve, in Manaus – AM (OA1); Mancio Lima in Acre (OA2) and Forestry station in Manaus-Am (OA3). The seeds were kept frozen at -20º C until they were processed. Sisgen registration: AF60078.

3.2 OBTAINING THE EXTRACTS WITH ULTRASOUND-ASSISTED SOLVENTS

The seeds (200g) were boiled for 20 minutes in water at 100°C in a closed 5L stainless steel container under a constant pressure system. After boiling, the seeds were dehulled and the homogenized and crushed grains were transferred to a 500 mL conical glass flask. The extraction was carried out in a UNIQUE ultrasonic bath, model USC - 1800, with a frequency of 40 KHz and a power of 155 Watts RMS, maintained at a temperature of 50 °C for 30 minutes. The solvent used was analytical grade n-hexane. A volume of 200 mL of the solvent was added to 60 g of biomass to carry out the hexane extraction (3x). The hexane extract was filtered and the remaining biomass was used for other purposes. After the evaporation of the solvents, the dry extract was quantified.

3.3 DERIVATIZATION OF THE SAMPLES

The samples were derivatized with N,O-bis(trimethylsilyl)-trifluoroacetamide (BSTFA) + 1% trimethylchlorosilane (TMCS) to select the free molecules that had not been hydrolyzed and the others with free hydroxyls. Two samples were used, with 10 mg of oil added to each 2 ml conical tube, followed by 50 µL of the derivatizer. The tubes were kept in an ultrasonic bath for 20 minutes at 30 °C. The solvent was evaporated at 35° C / 5 psi / 20 min, and 500 µl of the mixture n-hexane: CH2 Cl2 in a ratio of 1: 1 (v / v) were added to the tubes respectively. They were shaken for 10 seconds, and the contents were transferred to 2 mL glass vials with caps and septum and submitted for GC/MS analysis.

3.4 METABOLIC ANALYSIS OF TARGET SAMPLES BY GC-MS

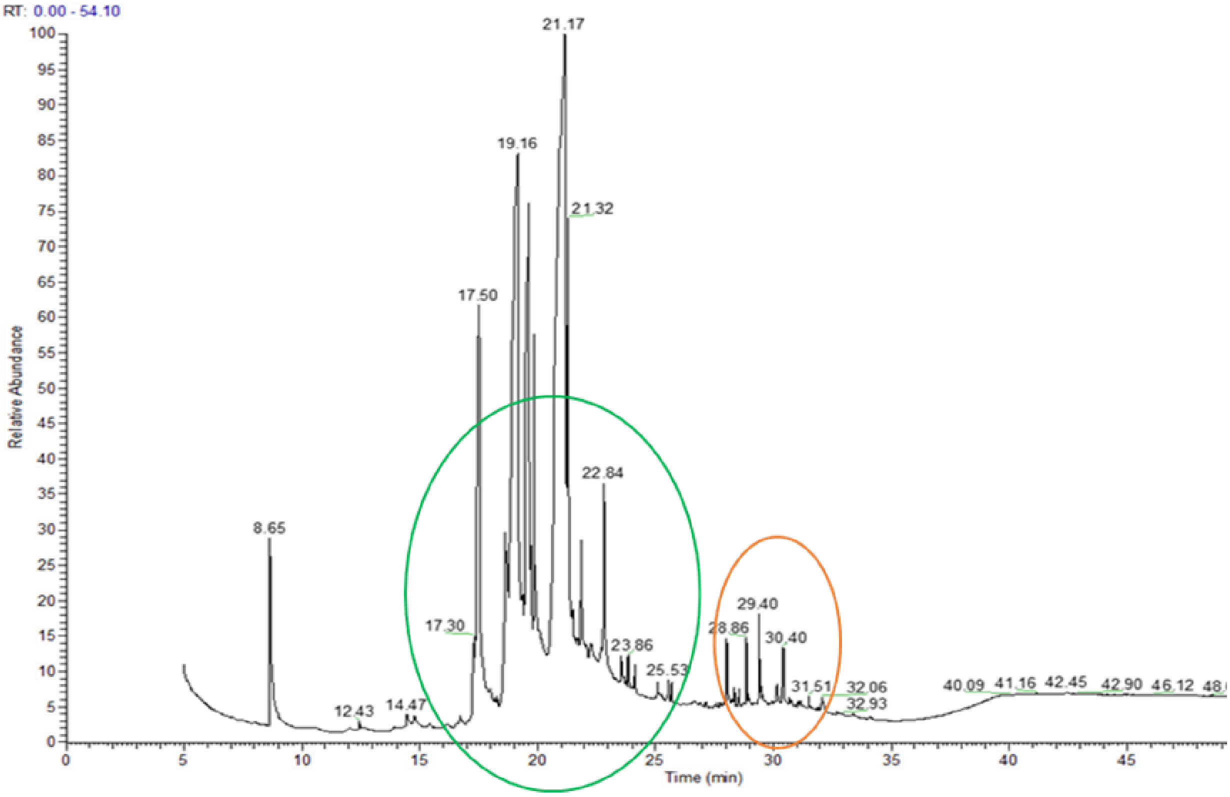
Mass spectrometry analyses were carried out using a Thermo Scientific Trace 1300 gas chromatograph (GC) coupled to an AI 1310 MS-ISQ Single Quadrupole autosampler mass spectrometer equipped with a ZB-5HT capillary column (30m x 0.25mm x 0.1µm), using helium gas as a carrier at a flow rate of 1mL/min. Sample injection of 1.0 µL in Splitless mode. The injector ran at 220 °C and the oven temperature adjustment started at 50 °C to 200 °C (8 °C / min.), remaining for 1 min, rising to 300 °C (15 °C / min.), being maintained for 5 min, rising again to 350 °C (15 °C / min.) and remaining for a further 9 minutes. The MS-ISQ was operated with the interface at 280 °C, the ionization source at 280 °C, the mass range (40-1000 Da) with 1 scan/s and electron ionization at 70 eV. The substances were identified by comparing the mass spectra with those of the commercial libraries NIST2011, WILEY2009, FAMES2011 x retention time. The lipid concentration was calculated by normalizing the peak area and validating the retention times.

4 RESULTS AND DISCUSSIONS

Andiroba oil has a group of substances belonging to the triterpenes, specifically the tetranortripernoids, known as limonoids, present in the unsaponifiable fraction. (Roy & Saraf, 2006). This fraction also contains steroid structures and can be observed through the lipidomic profile, where the fatty acids are presented in the form of methyl esters and for this reason are eluted more quickly (green circle), before the tetranortripenoids and steroids (orange circle), Figure 1.

Figure 1

Chromatogram of the lipid profile of andiroba oil

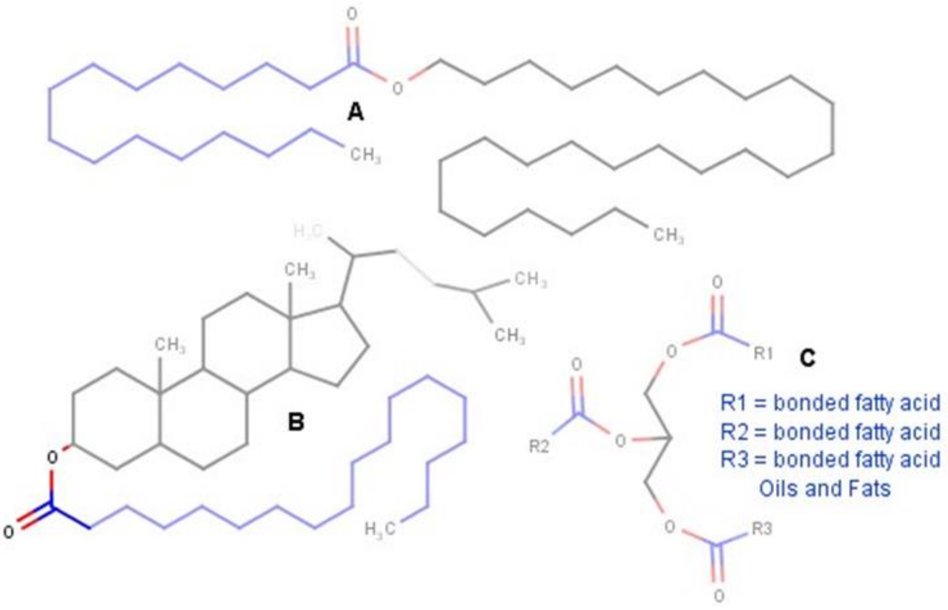


Chromatograms were obtained under special conditions to highlight the unsaponifiables. It can be seen that the amounts of steroids and limonoids are small compared to fatty acids. This relationship is based on the functions of biological activities, because in general, free molecules have greater biological activities than bound molecules. In this sense, fatty acids are linked to glycerol to form triacylglycerols, or to steroids or other structures such as higher alcohols to form waxes, Figure 2.

These aspects of bonding and connectivity to form neutral structures are important for minimizing the toxicity in molecules and thus avoiding damage to cells. In general, this is one of the reasons why free molecules have low concentrations.

Figure 2

Bound lipids present in vegetable oils

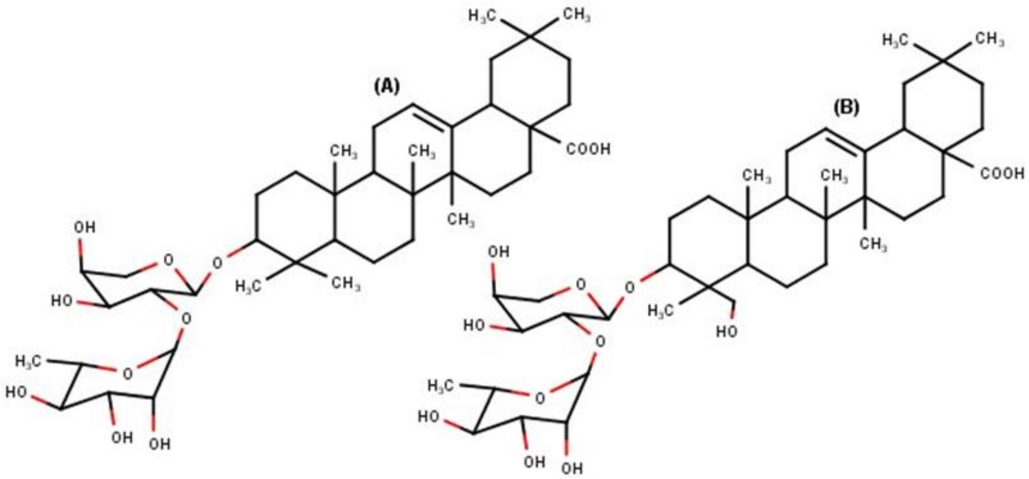


A= waxes, B= fatty acid-linked steroid, C= triacylglycerol

In this context, limonoids are free and dissolved in the oil or may be bound to the cell membrane. There are no known limonoids bound to sugars to form saponin analogs. These molecules are generally made up of triterpenes and steroids, Figure 3.

Figure 3

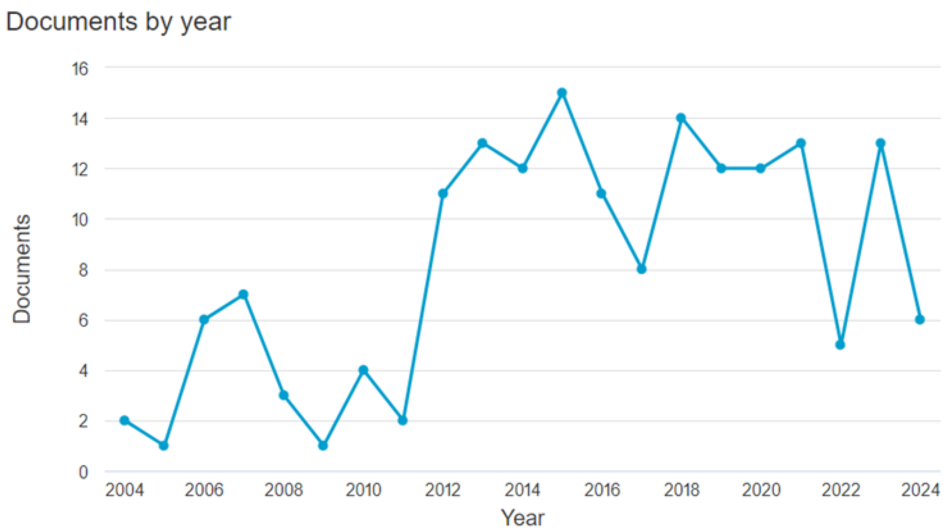
Triterpenes linked to sugars, forming saponins



Specifically, limonoids have a high antiinflammatory activity and act on lumbar inflammation, joint inflammation (arthritis, arthrosis, rheumatic arthrosis, etc.), peripheral circulatory inflammation (varicose veins and phlebitis) and strains (sprains, strains, insect bites and knocks). However, many uses are not limited to these symptoms but to inflammation in general, including infectious inflammation (Rodrigues et al., 2023). For this reason, andiroba oil is often mixed with copaiba oil, which has a high antimicrobial and parasitic potential (Dhorm Pimentel de Moraes, Tavares, Soares Rocha, de Paula, & Giorgio, 2018) But its use is little or never associated with the infectious aspect. In general, articles, theses and other scientific works don't focus on such specific points, describing general points, and it is for this reason that this work highlights such relevant points involving the potential of this oil, whether singular or associated. It can be seen that between 2004 and 2024 there is a growing trend in research into andiroba oil, mainly due to its anti-inflammatory properties, Figure 4. This demonstrates the demand for and interest in this oil due to its biological aspect in cosmetology, health, pharmacy, insect repellency and other activities that border on the economic aspect.

Figure 4

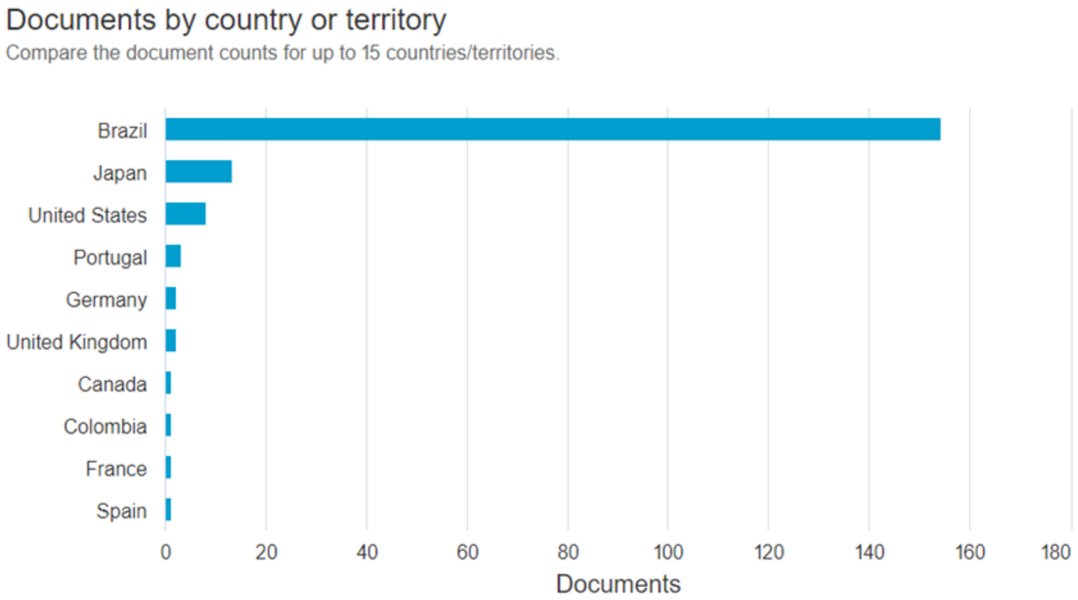
Publications on Andiroba oil



The sources of natural products with antiinflammatory potential have a more significant impact because this type of symptom is associated with body pain. In this sense, the search for active ingredients in plants is based on the scientific aspects related to easily accessible plants and the high productivity of their active ingredients. It can be seen that the countries involved in the use of plants to combat diseases are spread across Europe, Asia, and the Americas, and Brazil stands out in terms of publications related to andiroba (Figure 5).

Figure 5

Highlighting scientific publications on andiroba oil



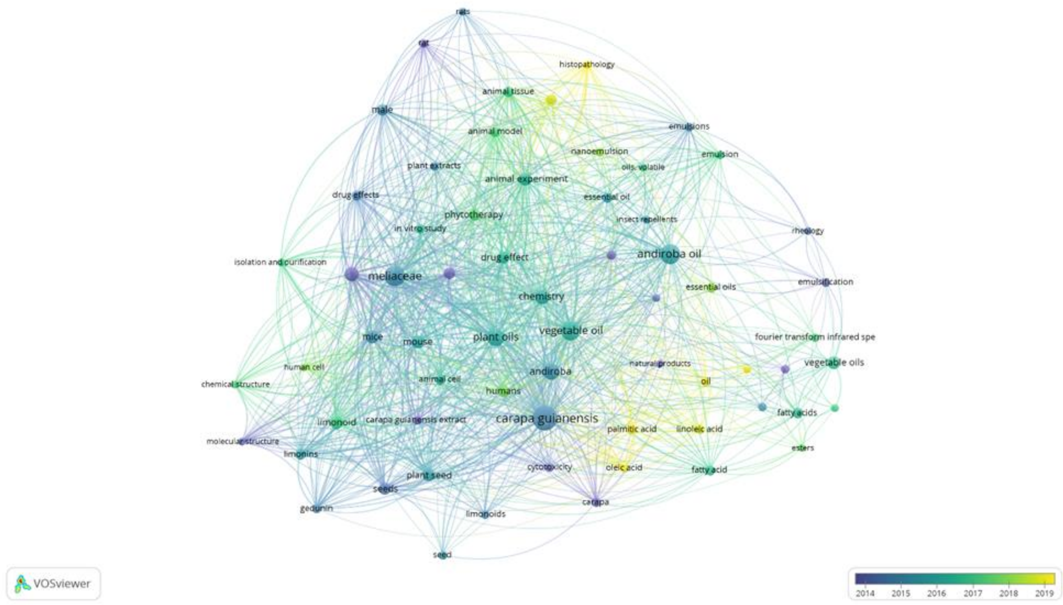
There are 154 documents published by Brazil

The study of andiroba oil is different because the keywords used are intensely related to "andiroba", "Meliaceae" and "Carapa guianensis". This is divided into the three most commonly used keywords, more recently, as of 2018, research has been directed towards the search for unsaturated fatty acids, w-3, w-9 and w-9 and it is in this aspect that andiroba oil has been explored. However, "emulsification" has also been explored due to the oil's high emulsification potential and the search for "limonoids", the most important target substances from the point of view of antiinflammatory activity. Figure 6 shows the keywords described by the authors in a search of 360 scientific articles on the Scopus database.

The most studied species in Brazil is C. guianensis Aubl, found in the northern states of Pará, Amazonas, Acre, Roraima, Rondônia and Amapá. It also occurs in the states of Maranhão, Mato Grosso and Bahia.

Figure 6

Bibliometrics with keywords and trends



It can be seen that on the occurrence map, the area delimited by the green line represents the northern states of Brazil, including the Amazon rainforest, with occurrence points. In the states outside the northern region, the occurrence points are represented by yellow dots Figure 7.

Figure 7

Distribution of Carapa guianensis Aubl in Brazil In: GBIF Secretariat (2024)

Source: GBIF: The Global Biodiversity Information Facility (2024). Available at https://www.gbif.org/what-is-gbif [July 07, 2024].

In this sense, the C. guianensis species has great potential for application and is strongly related to sustainable use by Amazonian peoples, including riverside communities. By hand, the oil is obtained by collecting the seeds, cleaning them, cooking them in water at 100º C until the kernel mass softens, resting them until they reach room temperature, between 28-32o C, removing the kernels manually with homemade utensils, and kneading the cooked kernels until they form a cake. This cake is left to rest in the shade or in the sun to release the oil, which is collected, processed and stored in jars with lids. (Santos & Salgado, 2020). In general, this oil is considered crude, or more modernly extra virgin oil. When the community or agro-family processes the seeds in large quantities, the excess oil is sent to oil marketing companies, cosmetics companies or fractionation companies for resale. This last aspect has a wide reach among Amazonian populations, as it is when it is purchased for external use to combat many inflammations.

In the industrial extraction of andiroba oil, factories use some more specific steps, such as cleaning the kernels, weighing, drying, pre-cooking and pressing, filtering or centrifuging, pumping the oil, packaging, storage and distribution. In some cases, the waste is also treated. Some of the stages are replaced, and this depends on the size of the factory and its technological conditions.

When it comes to commercial oil, quality control is essential and chemical analysis must accurately express the composition of the oil, especially the substances related to the active ingredient. In this case, andiroba oil was subjected to lipidomic analysis using the GC/MS technique after derivatization to integrate all the lipid substances present in the oil. This analysis revealed the presence of a diverse range of fatty acids, steroids and limonoids. Identifying these compounds, particularly the limonoids, is very promising for the development of sustainable applications aimed at generating antiinflammatory products.

Table 1

Comparison of the chemical composition of andiroba oil samples

In	Compounds	IK	TR Min.	AO-1 %	AO-2 %	AO-3 %
1	Glycerol		9,72	0,03	0,03	0,07
2	Lauric acid		15,28	-	-	0,2
3	Myristic acid		17,85	0,05	0,07	0,31
4	Palmitoleic acid		18,51	0,26	0,72	0,82
5	Palmitic acid		18,86	30,42	31,08	29,26
6	Oleic acid		20,86	55,68	59,78	58,07
7	Stearic acid		21,07	5,13	3,05	2,04
8	Arachidic acid		22,89	0,5	0,4	2,86
9	11-cis eicosanoate		23,04			0,3

10	Dodecanedioic acid	23,51	0,09	-	-
11	Dodecanoic acid	23,51	-	0,1	0,08
12	Docosanoic acid	25,42	0,04	0,02	0,3
13	Tricosanoic acid	25,67	-	-	0,23
14	Lignoceric acid	26,05	0,07	0,05	0,05
15	Tetracosanoic acid	26,4	-	-	0,4
16	Squalene	26,75	0,04	0,02	0,27
17	9-octadecenoic acid	28,81	0,04	-	-
18	Campesterol	29,53	-	-	0,11
19	Stigmasterol	29,75	-	-	0,1
20	Lanosterol	30,29	-	-	0,14
21	□-sitosterol	30,86	0,05	0,03	0,15
22	7-desacetyl-7-oxogedunin	33,97	-	0,02	0,09
23	7-oxogedunin	34,92	-	-	0,13
24	Desacetyl gedunin	35,04	0,02	0,02	0,14
25	Epoxidesacetyl gedunin	36,95	-	0,02	0,2
	another	-	7,58	4,59	3,68

TR: retention time, %=relative abundance; AO1, AO2, AO3= oils from AC and AM

The four limonoids identified in andiroba oil vary in their presence and concentration in the samples analyzed. It should be noted that gedunin is common in andiroba oil, although it can appear in a deacetylated form, as shown in Table 1. However, it can be detected, usually in residual concentrations, as observed in(Araujo-lima et al., 2018) e (Nascimento et al., 2019).

The search for natural alternatives to combat skin inflammation has been intensified in recent years in our research group, with studies carried out on Amazonian oilseeds and their effects on the enzymes Cyclooxygenases (COXs) and Lipoxynagenases (LOXs), which act in the biotransformation of arachidonic acid, an important cell regulator. (Wang et al., 2021). In this flow of the inflammatory chain, the mechanism of action of limonoids from andiroba, acting as NSAIDs, is presented as a candidate for inactivating these enzymes and making andiroba oil a promising source for generating products with high peripheral anti- inflammatory efficiency.

5 CONCLUSION

The study emphasizes the importance of andiroba oil in the bioeconomy and the role of riverside communities in using forest resources sustainably. The analysis of andiroba oil shows the wealth of valuable compounds and describes that the chemical composition of andiroba oil can vary with seasonality and the place of collection. Due to differences in the oil extraction process, which may also be associated with seasonality or the place of collection, there is always a variation in composition, which is reflected in the presence or absence of substances, specifically limonoids and steroids. The search for antiinflammatory substances has intensified in recent years because lipid compounds have great potential in Amazonian oilseeds. It is generally observed that the active antiinflammatory principles are found in the unsaponifiable fraction, and the application of in silico studies has emerged as an alternative to classify their effects on cyclooxygenase (COX) enzymes.

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REFERENCES

Araujo-lima, C. F., Fernandes, A. S., Gomes, E. M., Oliveira, L. L., Macedo, A. F., Antoniassi, R., … Felzenszwalb, I. (2018). Antioxidant Activity and Genotoxic Assessment of Crabwood (Andiroba , Carapa guianensis Aublet) Seed Oils. *Oxidative Medicine and Cellular Longevity*, *2018*, 1–11.

Armstrong, P. C., Kirkby, N. S., Zain, Z. N., Emerson, M., Mitchell, J. A., & Warner, T. D. (2011). Thrombosis is reduced by inhibition of COX-1, but unaffected by inhibition of COX-2, in an acute model of platelet activation in the mouse. *PLoS ONE*, *6*(5), 5–10. https://doi.org/10.1371/journal.pone.0020062

Budsberg, S. (2009). Nonsteroidal Antiinflammatory Drugs. In J. S. G. and W. W. Muit (Ed.), *Handbook of Veterinary Pain Management* (2nd ed., pp. 183–209). Elsevier. https://doi.org/10.1016/B978-032304679-4.10010-3

Busman, D. vieira. (2016). *Caracterização botânica da semente de Carapa guianensis Aublet, e estudos comparativos entre óleos de andiroba industrializado e fermentado, em formulações cosméticas como promotores de penetração cutânea* (Doctoral Thesis). Universidade Federal do Pará.

Chia, C. Y., Medeiros, Dantas, A., Corraes, A. de M. S., Manso, J. E. F., Silva, C. S. C., Takiya, C. M., & Vanz, R. L. (2018). Healing effect of andiroba-based emulsion in cutaneous wound healing via modulation of inflammation and transforming growth factor beta 3 1. *Acta Cirurgica Brasileira*, *33*(11), 1000–1015.

Christenhusz, M. J. M., & Byng, J. W. (2016). The number of known plants species in the world and its annual increase. *Phytotaxa*, *261*(3), 201–217. https://doi.org/ 10.11646/ phytotaxa.261.3.1

Cingolani, G., Panella, A., Perrone, M. G., Vitale, P., Di Mauro, G., Fortuna, C. G., … Scilimati, A. (2017). Structural basis for selective inhibition of Cyclooxygenase-1 (COX-1) by diarylisoxazoles mofezolac and 3-(5-chlorofuran-2-yl)-5-methyl-4-phenylisoxazole (P6). *European Journal of Medicinal Chemistry*, *138*, 661–668. https://doi.org/10.1016/j.ejmech.2017.06.045

Conab. (2017). Indicadores da Agropecuária. In *Companhia Nacional de Abastecimento* (Ano XXVI, Vol. 6, pp. 1–116). Brasilia, DF. Retrieved from www.conab.gov.br

Cook, E. F. (1946). History of the Pharmacopeia. *Food, Drug, Cosmetic Law Quarterly*, *1*(4), 518–531.

Costa-Tort, J., Flaviano, V. S. Di, González-Navarro, B., Jané-Salas, E., Estrugo-Devesa, A., & López-López, J. (2021). Update on the management of anticoagulated and antiaggregated patients in dental practice: Literature review. *Journal of Clinical and Experimental Dentistry*, *13*(9), 948–956. https://doi.org/10.4317/jced.58586

Cui, G., Li, Y., Yi, X., Wang, J., Lin, P., Lu, C., … Zhong, G. (2023). Meliaceae genomes provide insights into wood development and limonoids biosynthesis. *Plant Biotechnology Journal*, *21*(3), 574–590. https://doi.org/10.1111/pbi.13973

Dhorm Pimentel de Moraes, A. R., Tavares, G. D., Soares Rocha, F. J., de Paula, E., & Giorgio, S. (2018). Effects of nanoemulsions prepared with essential oils of copaiba- and andiroba against Leishmania infantum and Leishmania amazonensis infections. *Experimental Parasitology*, *187*, 12–21. https://doi.org/10.1016/j.exppara.2018.03.005

Ferraz, I. D. K., Camargo, L. L. C., & Sampaio, P. de T. B. (2002). Sementes e plântulas de andiroba (Carapa guianensis AUBL. e Carapa procera D.C.): Aspectos botânicos, ecológicos e tecnológicos. *Acta Amazonica*, *32*(4), 647–661.

Leandro, Y. A. da S., Jardim, I. N., & Gavilanes, M. L. (2017). The use of medicinal plants in health care practices by the residents of a communitty settlement in Anapu, Pará state. *Biodiversidade*, *16*(2), 30–44.

Lima Melro, J. C., Fonseca, S. A., Silva Júnior, J. M., Franco, S. P. B., Souza, M. A., Costa, J. G., … Santos, A. F. (2020). Ethnodirigid study of Medicinal plants used by the population assisted by the ""Programa de Saúde da Família"" (Family Health Program) in Marechal Deodoro - AL, Brazil. *Brazilian Journal of Biology*, *80*(1), 231. https://doi.org/10.1590/1519-6984.er214039

Martiniano, M. L. G., Machado Junior, C., Silva, F. V., & Silva, W. pereira da. (2023). Cooperação entre Empresas na Cadeia Produtiva : diagnose do Arranjo Produtivo de Semijoias de Limeira. *Revista Gestão & Conexões*, *12*(1), 8–27.

Miranda Júnior, R. N. C., Dolabela, M. F., Da Silva, M. N., Póvoa, M. M., & Maia, J. G. S. (2012). Antiplasmodial activity of the andiroba (Carapa guianensis Aubl., Meliaceae) oil and its limonoid-rich fraction. *Journal of Ethnopharmacology*, *142*(3), 679–683. https://doi.org/10.1016/j.jep.2012.05.037

Nardi-Santos, M. (2013). *Conhecimento ecológico local sobre as andirobeiras e a extração artesanal do óleo de andiroba em uma área de proteção ambiental, florestal de várzea periurbana* (Dissertação de Mestrado). Fundação Universidade Federal do Amapá. PPG em Biodiversidade Trópical. Retrieved from http://www2.unifap.br/ppgbio/files/2010/05/Mariane-Nardi-Dissertação-homologada.docx_.pdf

Nascimento, G. O., Souza, D. P., Santos, A. S., Batista, J. F., Rathinasabapathi, B., Gagliardi, P. R., & Gonçalves, J. F. C. (2019). Lipidomic profiles from seed oil of Carapa guianensis Aubl. and Carapa vasquezii Kenfack and implications for the control of phytopathogenic fungi. *Industrial Crops and Products*, *129*, 67–73. https://doi.org/10.1016 /j. indcrop. 2018.11.069

Reis, S., & Santos, A. S. (2021). Ultrasound-assisted lipid extractions , enriched with guianensis seeds and the application of lipidomics using GC / MS, 33160–33168. https://doi.org/10.1039/d1ra04776k

Rodrigues, E. S. R., Moreira, R. D. F., Santos, N. O., Soares, W. R. de A., Lima, E. S., & Aguiar, R. W. de S. (2023). Aspectos etnobotânicos, fitoquímicos e farmacológicos da espécie Siparuna guianensis Aublet: revisão sistemática. *Peer Review*, *5*(19), 456–475. https://doi.org/10.53660/987.prw2561

Roy, A., & Saraf, S. (2006). Limonoids: Overview of Significant Bioactive Triterpenes Distributed in Plants Kingdom. *Biological & Pharmaceutical Bulletin*, *29*(2), 191–201. https://doi.org/10.1248/bpb.29.191

Santos, A. S., Busman, D. vieira, Salgado, H. L. C., Reis, A. S. dos, Nascimento, G. de O., & Gonçalves, J. F. C. (2020). Aspectos botânicos e sazonal do gênero Carapa. In A.S. Santos (Ed.), *Aspectos Quimico, biológico, botânico, sazonal, microbiológico e biotecnológico das sementes de andirobeiras (Carapa spp.)* (1a ed., pp. 29–60). Curitiba: Appris.

Santos, Alberdan Silva, & Salgado, H. L. C. (2020). Produção do óleo de andiroba. In Alberdan Silva Santos (Ed.), *Aspectos Químico, Biológico, botânico, sazonal, microbiológico e biotecnológico das sementes de espécies de andirobeiras (Carapa spp.)* (1st ed., pp. 103–134). Curitiba: Appris.

Wang, B., Wu, L., Chen, J., Dong, L., Chen, C., Wen, Z., … Wang, D. W. (2021). Metabolism pathways of arachidonic acids: mechanisms and potential therapeutic targets. *Signal Transduction and Targeted Therapy*, *6*(1). https://doi.org/10.1038/s41392-020-00443-w.