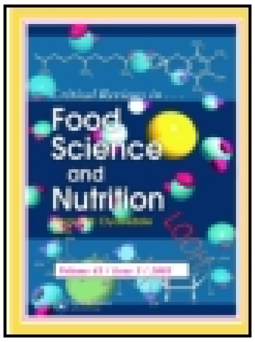

Critical Reviews in Food Science and Nutrition

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/bfsn20

Essential and fixed oils from Amazonian fruits: proprieties and applications

Andréia Ibiapina, Larissa da Silva Gualberto, Bianca Barros Dias, Bárbara Catarina Bastos Freitas, Glêndara Aparecida de Souza Martins & Antonio Alves Melo Filho

To cite this article: Andréia Ibiapina, Larissa da Silva Gualberto, Bianca Barros Dias, Bárbara Catarina Bastos Freitas, Glêndara Aparecida de Souza Martins & Antonio Alves Melo Filho (2021): Essential and fixed oils from Amazonian fruits: proprieties and applications, Critical Reviews in Food Science and Nutrition, DOI: 10.1080/10408398.2021.1935702

To link to this article: https://doi.org/10.1080/10408398.2021.1935702

Published online: 17 Jun 2021.

CRITICAL REVIEWS IN FOOD SCIENCE AND NUTRITION
https://doi.org/10.1080/10408398.2021.1935702

Taylor & Francis
Taylor & Francis Group

REVIEW

Essential and fixed oils from Amazonian fruits: proprieties and applications

Andréia Ibiapina[a], Larissa da Silva Gualberto[a], Bianca Barros Dias[a], Bárbara Catarina Bastos Freitas[a], Glêndara Aparecida de Souza Martins[a], and Antonio Alves Melo Filho[b]

[a]Laboratory of Kinetics and Process Modeling, Federal University of Tocantins, Palmas, TO, Brazil; [b]Federal University of Roraima, Boa Vista, RR, Brazil

ABSTRACT
The Amazon biome is rich in oilseed plant species, which have essential physical–chemical, nutritional and pharmacological properties, in addition to potential economic value for different biotechnological and industrial applications. In the extraction of fixed oils, some Amazon fruit that are oleaginous matrices are acquiring more prominence, such as tucumã (*Astrocaryum vulgare*), pupunha (*Bactris gasipaes*), buriti (*Mauritia flexuosa*), Brazil nut (*Bertholletia excelsa*), pracaxi (*Pentaclethra macroloba)*, patawa (*Oenocarpus bataua*), among others. These oilseed fruits have natural antioxidants, essential fatty acids, and good oxidative stability. The essential oils from these oilseed species have antibiotic and anti-inflammatory properties, in addition to the presence of natural antioxidants, such as carotenoids and tocopherols. Thus, Amazonian oilseed species are valuable resources. For these properties to be preserved during fruit processing, the process of extracting the oil is critical. More studies are needed on their properties and applications, seeking to add commercial value, and the optimization of oils and fats processing to obtain quality products. Therefore, this article aims to present Amazonian fruits' potential to obtain fixed and essential oils and possible application in the food industry.

KEYWORDS
Amazon biome; biodiversity; exotic oilseeds; vegetable oils

Introduction

The Amazon region has incredible biological biodiversity, both in animal and plant species. Vegetables have economic potential for several sectors, from extractive activities, food, and beverage processing to biofuels. However, the number of species in the region studied on an industrial scale is still low (Diniz et al. 2019; Lima and Portari 2019). Native fruits, which traditionally had local and seasonal consumption, gained attention from the domestic and foreign markets since 1988, with exposure of the Amazon forest to the world media (Homma et al. 2018).

Given this fruitful biodiversity, it is necessary to increase these fruits' value, which is still poorly characterized and explored by researchers (Negri, Berni, and Brazaca 2016). In nutritional terms, Amazonian fruits have abundant proteins, carbohydrates, fibers, lipids, vitamins, and minerals that provide an enriched diet. These fruits have large amounts of bioactive compounds and high antioxidant activity, both in the pulps and in the by-products produced by them, such as peels and seeds (Barros et al. 2017). These by-products may have a more significant amount and diversity of bioactive compounds than the edible portion (Can-Cauich et al. 2019).

The Brazilian Amazon region is also rich in oilseed plant species, with potential economic value for different industrial and biotechnological applications (Dabaja, Bizzo, and Pereira 2018). The vegetable oils and fats produced by these species have unique compositions, in addition to important physical–chemical and nutritional properties (Bezerra et al. 2017). It is estimated that 60 to 80% of the non-saponifiable fraction of fruits from the Amazon is bioactive compounds, predominantly unsaturated fatty acids, sterols, vitamin E, and carotenoids (Serra et al. 2019). Amazonian oils have great potential for medicinal, cosmetic, nutraceutical, and energy generation products and use in the food industry (Hidalgo, Nunomura, and Nunomura 2016).

Studies involving oleaginous fruits have been growing because they are possible alternative energy generation sources and present essential technological functions for the industry (Moura et al. 2019). The food industry shows an increasing demand for natural compounds to develop new preservatives against pathogenic microorganisms and those with deterioration capacity, as well as supporting the innovation of packages. These and other demands justify the exploitation of oilseed species that can contribute to the development of new technologies (Asbahani et al. 2015).

Thus, this review's objective is to present the potential for producing fixed and essential oils from different Amazonian fruits and possible design applications in the food industry.

CONTACT Glêndara Aparecida de Souza Martins glendarasouza@mail.uft.edu.br Federal University of Tocantins, Post Graduate Program in Food Science and Technology, Quadra 109 Norte, Avenida NS15, ALCNO-14 - Plano Diretor Norte, Palmas - TO, 77001-090, Brazil.

Amazonian fruits with potential for oil production

Bacupari (Garcinia gardneriana)

Bacupari (Figure 1) is considered a sweet and refreshing fruit, widely consumed fresh or processed with high energy value (78.69 Kcal/100 g). It has microbial, anti-inflammatory, anti-tumor activity (Schneider et al. 2020; Fernandez et al. 2021). It has a high content of carbohydrates (20.12 g/100 g), in addition to being a source of proteins (0.48 g/100 g), sugars (24.19%), ascorbic acid (0.90 mg/100 g) and phenolic compounds (104.58 to 264.43 mg EAG/100 g). Its lipid content is considerable for extracting essential oils (0.21 g/100 g) (Marques et al. 2018; Schneider et al. 2020). This species is a medium-sized tree found in forest formations on the Atlantic slope, mainly in the Amazon rainforest (Fernandez et al. 2021).

Tucumã (Astrocaryum vulgare mart.)

Tucumã (Figure 2) is highly nutritious, and its pulp is consumed both fresh and in processed form (Carneiro et al. 2017). The fruit is considered a source of lipids (40.49%), fibers (10.93 – 18.63%), vitamin C (14.35 mg/100g), minerals (2.58%), unsaturated fatty acids (68.77%), and high antioxidant potential (115.76 g/g DPPH). It is deemed ideal for food production for human consumption (Santos et al. 2018, Ferreira et al. 2008). Among the most abundant minerals in this fruit are iron, potassium, and manganese, making it an excellent mineral supplement, which can be used to control diseases such as iron deficiency anemia and hypokalemia (Santos et al. 2018). Tucumã is characterized by having low acidity (5.47 KOH/g), high β-carotene (11.600 μg – 21.800 μg/100g) content, and high energy value (412.73 Kcal/100g) (Azevedo et al. 2017) due to the average percentual of lipids present in its composition (40 – 62%) (Ferreira et al. 2008; Yuyama et al. 2008).

Pupunha (Bactris gasipaes)

Peach palm (Figure 3) is considered a highly nutritious and energetic fruit (391.86 kcal), with potential in the food industry associated with high content of carbohydrates (75.18%), proteins (3.96%), lipid index (8.22%), fibers (4.11%), carotene (194.69 µg/g) and minerals (1.91%), in addition to presenting antimicrobial activity (Brito, Alves, and Moreira 2017; Girón and Santos 2016). Peach palm is also a palm tree native to the Amazon. Its fruit are consumed by the people of the region, which is well known for its use in the production of "palmito" as well as an essential source of fixed oil (Santos et al. 2017).

Açaí (Euterpe oleracea)

Açaí (Figure 4) is one of the most researched fruits in the Amazon due to its excellent properties in macronutrients. In addition to the antioxidant properties rich in functional compounds, the contents of polyphenols, flavonoids, phenolic acids and other compounds also stand out in this fruit (Cedrim, Barros, and Nascimento 2018). This species has been considered as one of the new "superfruits" and also a functional food, because it is a source of energy (37.8 Kcal/100g), fibers (76.47), anthocyanins and minerals (0.41%), plus, high lipid composition (24.75%) and high content of important unsaturated fatty acids (70%), which helps in the prevention of several degenerative diseases (Nascimento et al. 2008).

Cupuaçu (Theobroma grandiflorum)

Cupuaçu (Figure 5) is a fruit widely consumed in its fresh and processed form. Despite having a high economic potential due to the use of the fruit in the food and cosmetics industries, it generates large amounts of waste, such as seeds, discarded in the environment, which are not explored and can supply various nutrients such as carbohydrates (26.4%), lipids (24.4%), fibers (22.2%), polyphenols (16.9%), proteins (14.2%) and minerals (5.2%) (Costa et al. 2020).

Buriti (Mauritia flexuosa)

Buriti (Figure 6) is a fruit of great interest in the food, cosmetic and pharmaceutical industry. It presents in its chemical composition compounds with important biological properties such as terpenoids, steroids, tocochromanols, organic, phenolic and flavonoid acids, in addition to presenting about 20% of lipidic content rich in unsaturated fatty acids such as oleic acid (65.6%) and a high energy value (592 kcal). It is a highly nutritious fruit, with yellow-orange pulp and bittersweet flavor (Bataglion et al. 2020); it has an endocarp surrounded by a spongy material made of starch and oil with a reddish-brown hard shell similar to a scale (Milanez et al. 2018).

Pracaxi (Pentaclethra macroloba)

Pracaxi (Figure 7) is a fruit of high nutritional value and has several foods, medicinal properties and insecticides (acting in the inhibition of proteases) (Dantas et al. 2017). Commonly known as "Gavilán tree", "pracaxi" or "pracachy", this species is an Amazonian tree that has been gaining prominence due to the high potential for eco-sustainable exploration. It produces a pod-shaped fruit that contains between 3 and 8 seeds, from which it is possible to extract the fixed oil. The fruit has considerable amounts of nutrients such as lipids (53.42%), carbohydrates (25.17%), proteins (15.50%) and ash (1.90%) (Teixeira et al. 2020). Pracaxi oil has about 53% oleic acid, which is one of the factors responsible for attributing functional properties to food (Costa et al. 2014).

Murumuru (Astrocaryum murumuru mart.)

The murumuru (Figure 8) palm is widely distributed in the Amazon Basin and produces fruit with red and woody bark, composed of almond and pulp. In addition, it is a medium-sized palm that grows preferentially in lowland soils in the

Amazon region (Marronato et al. 2016; Corrêa et al. 2020). Despite its economic potential, murumuru is little explored commercially due to the amount of thorns arranged in the stem of the leaves of the plant, making management difficult. Murumuru seed can contain up to 24% oil, with lauric (44%), myristic (27%), oleic (11%) and palmitic (9%) fatty acids present (Silva et al. 2010). It's also possible to extract oil from the murumuru pulp, and one example of product that can be found in the market that use this pulp oil, is the Cheysoap. Cheysoap is a product based on saponified triglycerides used as an additive in the manufacture of soap (Meneguetti and Siviero 2019).

Brazil nut (Bertholletia excelsa)

Popularly known as Brazil nut (Figure 9), the species Bertholletia excelsa is a tree known worldwide and one of the main export products of the Amazon. Each fruit has about 18 seeds with a hard and rough skin. It is rich in nutrients such as lipids (67.52%), proteins (14.28%), carbohydrates (6.56%), fibers (3.64%) and minerals (3.65%) in addition to high energy value (691 kcal) (Balbi et al. 2014). It has high energy density and a wide variety of trace elements and bioactive compounds, which are related to health benefits, antioxidant capacity and prevention of nutritional deficiencies. Also, Brazil nut production is free from chemicals used in pest control, which is why it is considered organic.

Copaíba (Copaifera langsdorfii)

Copaiba (Figure 10) is known for its medicinal and pharmacological benefits. The pulp of copaiba has 85% of hydrochloride, 5.51% of protein, 1.58% of ash and a lipid content of 4.20%. In addition, it contains a total polyphenol content of 217.37 mg/g. The resinous oil of copaíba is composed of volatile substances, corresponding to about 90% of the mass of the oil resin, and the other group is composed of nonvolatile substances (Batista et al. 2016; Azevedo et al. 2020).

Copaifera L. stands out among oilseeds for its diversity in terms of use, as well as in species, with a total of 28 species reported. Of these, 16 are in Brazil, 9 of them in the Brazilian Amazon, in states such as Maranhão, Pará, Tocantins, Amapá and Mato Grosso, being the subject of studies that demonstrated different biological activities through fractions of essentials oils (Gebara et al., 2016; Gurgel et al. 2019).

Fixed oils

The fixed oil present in Amazonian fruits can be found when extracted at room temperature in the form of oil (liquid) and fat (solid), which can be explained according to the degree of saturation of the fatty acid chain found. Brazil nuts (*Bertholletia excelsa*) and pracaxi (*Pentaclethra macroloba*) are examples of sources that supply oil at room temperature since they have a high content of monounsaturated (41,36–48,39%) and polyunsaturated (13,15–31,73%) fatty acids (Pereira et al. 2019).

In contrast, species such as murumuru (*Astrocaryum murumuru*) and tucumã (*Astrocaryum vulgare*) provide solid fats rich in lauric and myristic fatty acids. Due to their high saturated fatty acid content (88,41% and 88,97%, respectively), these last two products are solid at room temperature (Pereira et al. 2019).

The fatty acid profiles of the main oilseeds in the Amazon have a high level of unsaturation, particularly in palm species. Oleic (C18:1) and linoleic (C18:2) acids are the most abundant fatty acids in some palm species, possibly at higher levels than other vegetable oils. They are also precursors of eicosanoids and regulators of intracellular signaling (Serra et al. 2019).

Bacupari oil can be obtained from both seed and pulp. It can be a good source for use in the cosmetic or food industry due to its emulsifying characteristics and high oxidative stability, and a fair number of compounds such as tocols and carotenoids (Serra et al. 2019). The seeds can contain 8 to 9% oil, which can treat wounds and tumors (Araújo et al. 2019).

Some oilseed matrices in the region are gaining more and more prominence, such as the tucumã (*Astrocaryum vulgare Mart.*). Tucumã is a native palm that produces fruit with pulp (53.2%) and seed (24.5%). While the tucumã fruit's pulp provides an orange oil rich in polyunsaturated fatty acids, the almond produces a fat-rich in saturated lauric fatty acids (Pardauil et al. 2017; Pereira et al. 2019).

The fruit of the tucumanzeiro has good productivity in oil, even in acidic soils, from medium to low natural fertility (Franzini et al. 2016). Tucumã oil has a lipid composition with mono and polyunsaturated fatty acids, such as oleic, linoleic, and linolenic acid, and, also the presence of saturated fatty acids, such as palmitic and stearic (Costa et al. 2016). Despite its great potential for oil production with high vitamin A content, the use of tucumã is still restricted to the consumption of traditional and urban low-income communities.

Pupunha fruit has high oil concentration, with high content of linoleic and linolenic polyunsaturated fatty acids, representing up to about 40% of the composition (Restrepo, Estupinan, and Colmenares 2016). The oil extracted from pupunha pulp has characteristics that promote health quality when ingested, such as preventing cardiovascular diseases (Santos et al. 2020). This fruit's oil has an antimicrobial function due to secondary metabolites present in its chemical composition (Araujo et al. 2012; Brito, Alves, and Moreira 2017).

According to Singh and Jorge (2013), the lipid fraction of pupunha pulp showed a yield of 22.07% in oil, which was formed by a fraction of 62.86% of unsaturated fatty acids, with oleic acid as the primary (48.65%), and 37.13% saturated fatty acids. Higher percentages of palmitic (33.75%) and linoleic (6.59%) acids were observed among the quantified fatty acids. Pupunha oil has sufficient stability to be used in a process such as frying and spraying crackers and snacks, where it is used to maintain product quality and increase palatability (Singh and Jorge 2013).

Açaí oil is predominantly composed of unsaturated fatty acids, with emphasis on monounsaturated oleic acid (ω-9) and polyunsaturated, represented by linoleic (ω-6) and palmitoleic, as well as saturated acids, including stearic and palmitic (Souza et al. 2017). According to Rufino et al. (2011), the antioxidant capacity of açaí oil exceeds that found for other extra virgin oils and is a dietary fiber source. It presents an excellent potential for nutritional, industrial, and sanitary applications.

Açaí oil also has a high pharmacological potential due to its high antioxidant and phytochemical capacity; however, this product's intake must be controlled and monitored since this oil can also present cytotoxic characteristics to the liver and thyroid (Marques et al. 2019). In vitro and in vivo studies have shown that açaí oil in nanoemulsion with Tween 80 surfactant and ultrapure water can be considered an effective photosensitizer for melanoma treatment (Fuentes et al. 2017). The addition of açaí oil to lactating cows' diet increased the antioxidant activity in whey and milk. Moreover, it presented the ability to promote milk production and quality in dairy sheep under thermal stress (Santos et al. 2019).

From cupuaçu almonds an oil is obtained with a high percentage of unsaturated fatty acids and a smooth and pleasant flavor. It has active antioxidant substances, a low percentage of theobromine, and high content of unsaturated fatty acids (58.29%). It is considered a suitable product for the cosmetics, pharmaceutical, textile, chocolate, beverage, and food industries (Criollo, Criollo, and Aldana 2010). The most abundant fatty acid in Cupuaçu butter is oleic acid (C18:1) (43.17%), followed by stearic acid (C18:0) (33.91%). Cupuaçu seed has approximately 62% lipid content and has characteristics similar to cocoa butter (Azevedo, Kopcak, and Mohamed 2003, Serra et al. 2019).

Another attractive palm is the buriti (*Mauritia flexuosa* Mart), whose oil extracted from its fruit is characterized by being an essential source of proteins, energy, and vitamins. Pereira et al. (2018), when studied the antibiotic activity promoted by the fixed oil of buriti, found a higher content of unsaturated fatty acids (89.81%) when compared to saturated fatty acids (10.19%). The authors also demonstrated that buriti oil is a valuable source of oleic acid (89.81%). According to Speranza et al. (2016), due to its high content of oleic acid (65.6%) and low content of linoleic fatty acids (4.9%), buriti oil has more resistance to oxidation than most liquid oils. Besides, it is considered one of the richest known sources of β-carotene.

From the buriti pulp it is possible to extract the oil whose main components are palmitic (18.7%), stearic (1.5%), oleic (76.7%), linoleic (1.5%), linolenic (0.7%) and arachidic acid (0.5%) (Lima et al. 2017). The buriti fruit has about 1.7% lipids (Canuto et al. 2010), with a high carotene content (Willerding et al. 2012).

Oils such as buriti and pracaxi can be considered functional foods and are the right ingredients for functional food production due to natural antioxidants (methyl tocols and carotenes) that can improve human health (Serra et al. 2019).

The pracaxi oil has different fatty acids in its chemical composition, emphasizing oleic (ω-9) (47,3–53,5%), linoleic (ω-6) (11,7–13,1%), behenic (16.1–25.5%), and lignoceric (12,5%) acids. Its seeds contain about 30% of oil on a dry basis, being used for various industrial purposes, such as cooking oil, manufacture of candles, preparation of medicines, cosmetics, lubricants, butter, and soaps (Teixeira et al. 2020; Oliveira, Silva, and Rocha 2019; Meneguetti and Siviero 2019).

From the seed of murumuru, it is possible to extract approximately 42% of a whitish and semi-solid fat called murumuru butter, which can be used as a drying agent in the paint industry, an emollient in the cosmetics industry, or for the manufacture of soaps and creams. The murumuru butter is rich in lauric (49,6%), myristic (28,25%), palmitic (6,53%), stearic (2,57%), linoleic (3,14%) and oleic (6,85%) acids, also having phytosterols, emphasizing the β-sitosterol. Furthermore, it presents potential as an alternative raw material for biodiesel production (Marronato et al. 2016; Corrêa et al. 2020; Lima et al. 2017). Futhermore, murumuru butter nanoparticles show an excellent potential for use as a system for encapsulating lipid-soluble bioactive compounds (Meneguetti and Siviero 2019; Serra et al. 2019).

The oil extracted from Brazil-nut represents about 65% of its composition, being rich in magnesium, thiamin, selenium, phenolic compounds, antioxidant properties, and, also, presenting a pleasant odor and light-yellow color (Martins, Santos, and Faria 2020; Costa, Santos, et al. 2020). It also has application in the cosmetics sector due to its emollient, nourishing, and lubricating action and in the food and handicraft sectors. (Balbi et al. 2014; Vilhena et al. 2020). Its high content of unsaturated fatty acids, linoleic acid, linolenic acid, β-tocopherol, and β-sitosterol gives the Brazil-nut antioxidant and cholesterol prevention properties (Chunhieng et al. 2008).

The relatively high level of polyunsaturated fatty acids in Brazil nut oil (40% on average) is largely due to the content of linoleic acid (about 41%). However, it has higher amounts of stearic acid (up to 12%) and lower amounts of oleic acid (about 30%), and is also considered relatively rich in saturated fatty acids, with about 26%. In addition, Brazil nut oils have high levels of squalene and low or moderate levels of total sterols (Maestri et al. 2020; Serra et al. 2019).

Among the known oil species are also açaí (Euterpe oleracea) and the Brazil nut (Bertholletia excelsa) Both species have more than 70% of unsaturated fatty acids in their composition and proven antioxidant potential. The most used means for extracting the Brazil nut's oil is the hydraulic or mechanical pressing with the almonds' previous heating. For açaí, the process is generally carried out without breaking seeds, using solvents or enzymes (Junior 2019; Vilhena et al. 2020).

Other sources reported by Junior (2019) are andiroba (Carapa guianensis Aubl.) and copaiba (Copaifera langsdorfii). Both fruits present oils that are popularly known due to their anti-inflammatory properties. However, unlike the others, copaiba is a resinous species. The copaiba oil is extracted from the trunk of this plant and receives this name because it consists of a mixture of the oil with a nonvolatile resinous part (Ferreira et al. 2017).

The resinous oil of the copaiba trunk is known for its anti-inflammatory, analgesic, healing, antipsoriatic, antigenotoxic properties, among others, in addition to its antioxidant capacity (Batista et al. 2016; Azevedo et al. 2020). The resin of copaiba oil accumulates in the cavities of the tree trunk from which it is extracted. After filtration, the oil appears in a consistent fluid state, with a yellow-brown to light green color, an aromatic odor, and a typically bitter taste (Aguilar et al. 2013).

Vegetable oils from the Amazon are extracted mainly by mechanical pressing of oilseeds, using a filter press apparatus. The basic processes for refining crude vegetable oils involve flaking, bleaching, de-acidification, and deodorization (Oliveira et al. 2016).

Jaramillo et al. (2019), in their study on the impact of the extraction model on the lipidomic profile of oils obtained from selected fruits from the Amazon, demonstrated that there is a significant difference in the composition of oils extracted by solvent when compared to those extracted by mechanical pressing. In the fruits studied, which were açaí, buriti, and patawa, solvent extraction helped increase diacylglycerides' concentration. Since diacylglycerides have surfactant activity, the oils extracted by the solvent can behave in different ways than the mechanically extracted oils.

The characterization of these fixed oils and fat's physical properties is essential to promote their industrial application. In general, these properties are directly related to the triacylglycerol (TAG) composition. An example is the oil viscosity, which increases with the triglyceride chain's length and decreases according to the unsaturation degree (Pereira et al. 2019; Oliveira et al. 2016).

According to Serra et al. (2019), Amazonian oils have high oxidative stability, such as buriti oil (69 h in OSI at 100 °C), due to the high content of saturated fatty acids, such as lauric, myristic, and palmitic. This composition positively influences variables such as melting point and saponification. In this sense, Table 1 presents some properties of fixed oils from Amazonian fruits.

Essential oils

Essential oils (EOs) are aromatic compounds produced as secondary metabolites by plants. They present in their composition complex mixtures of volatile and nonvolatile compounds, generally lipophilic and with low water solubility, classified into alcohols, aldehydes, esters, and ethers, ketones, oxides, phenols, terpenes, carotenoids, and flavonoids (Donsí and Ferrari 2016; Seow et al. 2014; Liaqat et al. 2019).

EOs can be extracted from petals, leaves, bark, roots, seeds, and resin by distillation, pressing, and solvent extraction. They are widely used in aromatherapy and are very popular in gastronomy, psychology, cosmetics, and perfumery. They are usually administered by inhalation, direct ingestion, massage, and bathing. Essential oils are active against various microorganisms such as viruses, fungi, protozoa, and bacteria (Silva et al. 2019).

OEs are known for their antiseptic properties and their pleasant fragrance. They protect the plants against predators and pollinators' attraction through natural volatile fractions that evaporate at room temperature. Most of OEs are composed of derivatives of terpenoids or phenylpropanoids. However, the terpenoids are more abundant and have low molecular mass (Junior 2019).

According to Asbahani et al. (2015) and Seow et al. (2014), OEs are synthesized in various plant organs to protect against external agents, such as UV light, herbivores, insects, and pathogens. EOs can start to act when they are released by humidity variation or mechanical action. They are accumulated and stored in specialized structures and located on plants' surfaces, such as the secretory glands, or in internal cellular organs, such as vacuoles, due to these oils' high molecular reactivity (Dima and Dima 2015). In the search for natural and sustainable alternatives that can replace synthetic pesticides and fungicides, the EOs are gaining more and more space due to their antimicrobial, antiviral, and antifungal characteristics since they are biologically active and economically viable (Saxena, Sharma, and Maity 2020; Yun et al. 2018; Silva et al. 2019).

Several Amazonian fruits produce significant amounts of essential oils, such as andiroba, buriti, copaíba, cupuaçu, murumuru, patawa, and tucumã, as shown in Table 2. Among the EOS produced by Amazonian fruits, the EO of copaíba can be highlighted. Copaíba essential oil is a concentrated liquid obtained by steam distillation of copaiba's oleoresin. This oil is widely used in the cosmetics sector for its fragrant properties, as an odor fixer, as a component in the manufacture of creams, soaps, shampoos, and hair conditioners, and even in the food sector, as a flavoring agent in foods and beverages (Urasaki et al. 2020).

The chemical composition of the essential oil of buriti bark has been studied, putting the species in the spotlight based on advances in chemical-pharmacological knowledge. This is due to the presence of tannins and flavonoids in its extract, which are possibly responsible for the antimicrobial activity presented by the plant. In addition, it has antimicrobial power, with Minimum Inhibitory Concentration (MIC) $\geq$ 1024 μg.mL-1 for all standard and multiresistant bacterial strains, also presenting a synergistic effect on Staphylococcus aureus (Rezende et al. 2020).

The essential oil of copaíba has a bacteriostatic behavior and activity against *Staphylococcus aureus* with a minimum inhibitory control of 62.5 μg mL^{-1} (Marangon et al. 2016). Its essential oil is partially formed by compounds of volatile sesquiterpenes, mainly β-caryophyllene (50–52%), with smaller amounts of other eight sesquiterpenes (Aguilar et al. 2013).

Amazon oils in the food industry

With the increase in health implications related to the consumption of low nutritional value foods, the search for a

Table 1. Properties of fixed oils of Amazonian fruits obtained by different extraction methods.

Fruit	Extraction method	Approximate oil yield	Extracted oil properties	Main compounds identified	References
Tucumã (Astrocaryum vulgare)	Cold press	≅40%	High concentration of oleic acid; Presence of saturated fatty acids, such as palmitic and stearic.	Oleic acid - 62%; Palmitic acid - 23%; β-Carotene - 21.842,74 μg/100g	Ferreira et al. (2008), Villela et al. (2014), Pardauil et al. (2017)
	Supercritical CO_2	≅33%	High carotenoid content and pro-vitamin A activity; Anti-carcinogenic and antimicrobial; High content of unsaturated fatty acids and carotenoids	Carotenoids -1065–2100 ppm; Oleic acid - 64.14–73.81%; Palmitic acid - 22.60–26.49%.	Costa et al. (2016)
Buriti (Mauritia flexuosa)	Cold press	≅38%	Antioxidant potential; Healing, anti-inflammatory and antibiotic; High concentration of oleic acid, useful in the food industry as frying oil; High content of unsaturated agents; High content of tocopherols and carotenoids; High oxidation stability.	Oleic acid - 65.6%–68.8%; Palmitic acid - 19.2%–19.4%. Tocopherol content: 2364.1 mg / kg with 93% of the isomers α-tocopherol and γ- tocopherol. β-carotene: 781.6 mg / kg. Oxidative stability: 69 h in OSI at 100 ° C.	Speranza et al. (2016), Pardauil et al. (2017), Serra et al. (2019), Elisia et al. (2013)
	Bligh-dyer	≅38%	Source of vitamin A and vitamin E. Source of antioxidant compounds.	Oleic acid 77.5%; Palmitic acid - 18.9%; α-tocopherol - 641 μg/g.	Darnet et al. (2011)
	Microwave	≅37%	High concentration of oleic acid.	Oleic acid - 86.59%; Palmitic acid - 12.31%.	Mosquera et al. (2012)
	Soxhlet with hexane	≅22%	Presence of specific agents that favor the formation of biodiesel with high volatility	Palmitic acid, - 18.7%; Estearic acid - 1.5%; Oleic acid - 76.7%.	Lima et al. (2017)
Pracaxi (Pentaclethra macroloba)	Cold press	≅36%	High concentration of vitamin E, carotenoids and antioxidant activity	Oleic acid - 72.16%, Linoleic acid - 18.84%; γ-tocopherol - 416.13 ± 2.69 ppm; α-tocotrienol - 93.53 ± 7.75 ppm.	Serra et al. (2019), Teixeira et al. (2020)
Brazil nut (Bertholletia excelsa)	Cold press	≅75%	High concentration of vitamin E, carotenoids and antioxidant activity	Linoleic acid- 41.23%; Oleic acid - 32.03%; Palmitic acid -14.77%;	Freitas et al. (2007), Serra et al. (2019)
Copaíba (Copaifera langsdorfii)	Cold press	≅75%	Anti-inflammatory, antiseptic and antirheumatic; Atividade Antimicrobiana Antiblenorrhagic, anti-tetanus, anti-herpetic, anti-cancer, anti-tumor, anti-asthmatic	Diterpenic acids and sesquiterpenes - 55–60%; Linoleic acid - 45.34%; Oleic - 30.96%; Palmitic acid - 12.71%.	Junior (2019), Meneguetti and Siviero (2019), Stupp et al. (2008)
	Bligh-dyer	Not described	Antiinflammatory, antitumor, antimicrobial and healing activity; antiseptic and antitumor potential.	Sesquiterpenes - 76.5%.	Veiga et al. (2007), Garcia and Yamaguchi (2012)
Andiroba (Carapa guianensis Aubl.)	Cold press	≅30–70%	Anti-inflammatory, antiseptic and antirheumatic, insecticides, antidiarrheal, antirheumatic, emollient, febrifuge, helminth, liver, purgative, repellent, tonic and vermifuge;	Oleic acid- 45–58%; Linoleic acid - 6–14%.	Junior (2019), Meneguetti and Siviero (2019)
Bacaba-de-leque (Oenocarpus distichus)	Supercritical CO_2	≅45%	High concentration of phenolic compounds	Oleic acid - 66%; Palmitic acid- 17%; Linoleic acid - 12%; The total content of phenolic compounds was 4.14 ± 0.30 mg GAE / g (mg of gallic acid equivalents / g of sample).	Cunha et al. (2019)
Noz sapucaia (Lecythis pisonis)	Supercritical propane	≅93%	High concentration of polyunsaturated agents and triglycerides	Oleic acid - 42.18%; Linoleic acid - 35.83%; Palmitic acid - 15.22%.	Teixeira et al. (2018)
Patawa (Oenocarpus bataua)	Bligh-Dyer	≅29%	Optimal ratio of saturated / unsaturated fatty acids. Source of vitamin E.	α-tocopherol - 78,5%.	Darnet et al. (2011)

Table 2. Properties of essential oils from Amazonian fruits.

Fruit	Extracted oil properties	References
Tucumã (*Astrocaryum vulgare*)	Anti-inflammatory, antioxidant, hypoglycemic and hepatoprotective effect	Rezende et al. (2020)
Buriti (*Mauritia flexuosa*)	Modulator of aminoglycoside activity	Rezende et al. (2020)
	Antimicrobial effect against *C. Gloeosporioides* and *Staphylococcus aureus*	Ferreira et al. (2012), Batista et al. (2012)
	Antioxidant, anti-inflammatory and healing effect	Silva et al. (2020), Batista et al. (2012)
Murumuru (*Astrocaryum murumuru*)	Potential inhibitor of phytopathogens	Meneguetti and Siviero (2019)
Copaíba (*Copaifera langsdorfii*)	Antimicrobial, emollient, bactericidal and anti-inflammatory activity	Rezende et al. (2020), Marangon et al. (2016), Meneguetti and Siviero (2019)
	Anti-blenorrhagic, skin-healing, anti-inflammatory, diuretic and expectorant agent	Silva et al. (2012)

Table 3. Potential sector application of different oils from Amazonian fruits.

Fruit	Oil	Industrial sector	References
Bacupari (*Garcinia gardneriana*)	Fixed	Cosmetics and food industries	Serra et al. (2019)
Tucumã (*Astrocaryum vulgare*)	Fixed	Cosmetics and food industries	Pardauil et al. (2017), Costa et al. (2016)
Cupuaçu (*Theobroma grandiflorum*)	Fixed	Cosmetics, food and pharmaceutical industries; chocolate production; textile sector	Serra et al. (2019)
Buriti (*Mauritia flexuosa*)	Fixed	Cosmetics and food industries; biofuels	Pardauil et al. (2017), Lima et al. (2017), Serra et al. (2019)
	Essential	Cosmetics	Santos et al. (2021)
Pracaxi (*Pentaclethra macroloba*)	Fixed	Biofuels	Serra et al. (2019)
Murumuru (*Astrocaryum murumuru*)	Fixed	Cosmetics and food industries; paints production; biofuels	Marronato et al. (2016), Corrêa et al. (2020), Serra et al. (2019)
Castanha-do-brasil (*Bertholletia excelsa*)	Fixed	Food industry	Serra et al. (2019)
Copaíba (*Copaifera langsdorfii*)	Fixed	Pharmaceutical industry	Junior (2019), Meneguetti and Siviero (2019)
	Essential	Cosmetics, food and pharmaceutical industries	Urasaki et al. (2020)
Babaçu (*Attalea speciosa*)	Fixed	Food industry	Serra et al. (2019)

varied diet with fruit and vegetables has gained more attention. Some plant constituents bring health benefits and are associated with bioactive compounds such as linolenic acids, linoleic acids, and fibers. These constituents have preventive and supporting functions in treating pathologies, especially chronic non-communicable diseases and cardiovascular diseases (Bankoff et al. 2017; Santos, Klauck, et al. 2019). Studies on Amazonian food sources have been carried out to diversify and raise food quality, both for local communities and the world public, since characteristics such as the levels of functional compounds and the presence of polyunsaturated fatty acids and phenolic compounds with antioxidant activity justify the use of fruits from the Amazon. This insertion of Amazonian food sources has been happening with the pulps production and various products as mixed juices, sweets, and enriched drinks (Santos, Klauck, et al. 2019).

The Amazon biome has many species with oleaginous potential, with oils and fats with excellent physicochemical properties. Some Amazonian products used by the food industry still have a strong relationship with extractivism in their production chains, such as Brazil nuts, andiroba, copaíba, murumuru, buriti, and babaçu (Diniz et al. 2019). In addition to their use in the food industries, Amazonian oils, both fixed and essential, are used by other industrial sectors (Table 3). Some matrices' qualities are already recognized, such as that of pracaxi oil, considered a natural source of benzene acid. Pracaxi oil has properties that allow the preparation of low-calorie products. The cupuaçu fat is another example used in the food industry to prepare various products such as vegetable creams, margarine, chocolates, and special fats for frying, baking, and confectionery use (Bezerra et al. 2017).

According to Santos et al. 2017, oils and fats with high concentrations of ω-9 acids, followed by small concentrations of ω-3 and ω-6, can be obtained from açaí (pulp), ata brava (seeds), bacaba (green fruit pulp), buriti (pulp), buritirana (pulp), yellow murici (seeds), red murici (seeds), piaçaba braba (pulp), tucumanzinho (pulp), red pupunha (pulp) and yellow pupunha (pulp), from different regions. For the authors, the tucumanzinho presented contents of ω-9 close to that of olive oil, indicating that the Amazonian biodiversity is capable of supplying fruits with essential fatty acids.

Challenges and future perspectives

The incentive for research to expand agricultural development possibilities with native plants can increase Amazonian oils fruits participation in the national and international markets without expanding deforestation. This stimulus will make it possible to recover already degraded areas through cultivation and provide socioeconomic inclusion to family farmers (Homma et al. 2012). Another fundamental point is the issues related to the environment and sustainability. Protecting the most significant amount of its area to guarantee biodiversity, water resources, global climate balance, and

Figure 1. Bacupari fruit (*Garcinia Gardneriana*).

Figure 2. Tucumã (*Astrocaryum vulgare Mart.*).

Figure 3. Pupunha (*Bactris gasipaes*).

Figure 4. Açaí (*Euterpe oleracea*).

Figure 5. Cupuaçu (*Theobroma grandiflorum*) (Souza and Souza 2018).

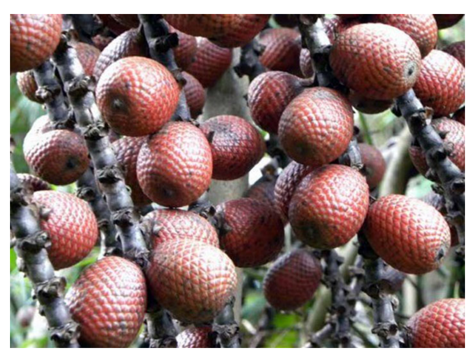

Figure 6. Buriti (*Mauritia flexuosa*) (Ferreira et al. 2018).

ensure the population's survival are significant challenges related to the Amazon biome (Homma et al. 2012).

Some of the Amazonian fruits can be considered as superfoods, as they are natural and of superior nutritional quality. This fact may represent a challenge related to important socio-environmental impacts, since the growing demand for superfoods and their by-products can be reversed in intensive agricultural production practices. The increase in demand for açaí, for example, has led to the rapid expansion of plantations and considerable changes in the forest structure. Thus, more research is needed to ensure the development of a production scheme that supports both forest conservation and the production of these fruit (Magrach and Sanz 2020).

In a general context, some species' seasonality in the Amazon Region represents the common challenge of their availability in the off-season. The seasonality can be seen as an impulse to process these fruits to become available to the consumer throughout the year, without directly depending on seasonality. As highlighted by Homma et al. (2012),

Figure 7. Pracaxi (*Pentaclethra macroloba)* (Silva and Durigan 2018).

Figure 8. Murumuru (*Astrocaryum murumuru Mart.*) (Bezerra 2012).

Figure 9. Brazil nut (*Bertholletia excelsa*) (Cavalcanti 2014).

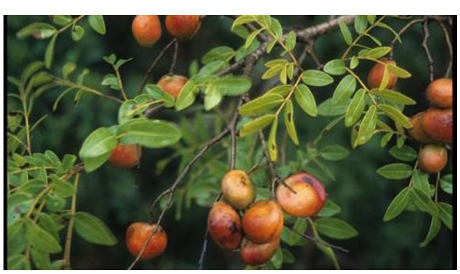

Figure 10. Copaíba (*Copaifera langsdorfii*) (World of Oils 2020).

vegetable oil from plants such as andiroba, copaíba, tucumã, and others, shows itself as an excellent opportunity to generate jobs and income in Amazonian communities. This vegetable oil from Amazonian species can also produce less polluting and better-quality biodiesel.

It is important to consider that some fruit species have particular challenges related to their technological characteristics, such as the murumuru (*Astrocaryum murumuru*), which, despite its economic potential, is little explored commercially because of its thorns (Meneguetti and Siviero 2019). Another case is pupunha, which presents difficulties at the time of oil extraction due to the formation of an emulsion with starch and water, making the use solvents necessary for its extraction.

Despite all the challenges, the Amazon oils are valuable resources with good prospects for industrial use and potential oxidative stability. Further studies are needed to optimize oils and fats processing to obtain a uniform quality product, and adding commercial value, such as applying new extraction methods and refining steps, when necessary. Also, in vivo tests on animals and humans are essential to assess the bioavailability of Amazonian fruit compounds (Serra et al. 2019).

Acknowledgements

The authors thank the Coordination for the Improvement of Higher Education Personnel (CAPES, Brazil) and the National Council for Scientific and Technological Development (CNPq, Brazil) for financial support.

Disclosure statement

The authors reported no potential conflict of interest.

ORCID

Andréia Ibiapina http://orcid.org/0000-0003-2523-9555
Larissa da Silva Gualberto http://orcid.org/0000-0002-7335-1771
Bianca Barros Dias http://orcid.org/0000-0002-2927-1491
Bárbara Catarina Bastos Freitas http://orcid.org/0000-0002-5059-4383
Glêndara Aparecida de Souza Martins http://orcid.org/0000-0002-3813-1028

References

Aguilar, C. A. L., K. R. D. S. Lima, M. C. Manno, F. B. Tavares, V. P. D. Souza, and D. L. Fernandes Neto. 2013. Effect of copaiba essential oil on broiler chickens' performance. *Acta Scientiarum. Animal Sciences* 35 (2):145–51. doi: 10.4025/actascianimsci.v35i2.15376.

Araújo, F. O., M. E. C. Moreira, C. F. Lima, R. C. L. Toledo, A. R. de Sousa, M. P. Veloso, and H. S. D. Martino. 2019. Bacupari (Garcinia brasiliensis) extract modulates intestinal microbiota and reduces oxidative stress and inflammation in obese rats. *Food Research International* 122:199–208. doi: 10.1016/j.foodres.2019.04.012.

Araujo, M. L., C. F. C. Silva, A. L. Melhorança Filho, R. M. de Souza, and W. S. Oliveira. 2012. Atividade antimicrobiana do óleo de duas espécies (Bactris gasipaes Kunth e Bactris dahlgreniana) de pupunha frente ao crescimento de Staphylococcus aureus. *Ensaios e Ciência* 16 (3):21–27.

Asbahani, A. E., K. Miladi, W. Badri, M. Sala, E. H A. Addi, H. Casabianca, and A. Elaissari. 2015. Essential oils: From extraction to encapsulation. *International Journal of Pharmaceutics* 483 (1–2):220–43. doi: 10.1016/j.ijpharm.2014.12.069.

Azevedo, V. S., A. S. Araújo, M. B. Sousa, M. S. Barros, and J. A. Rocha. 2020. Prospecção Científica e Tecnológica da Tuberculose no Maranhão e o Uso Medicinal da Copaifera Langsdorffii no Tratamento. *Cadernos de Prospecção* 13 (3):707.

Azevedo, A. B. A., U. Kopcak, and R. S. Mohamed. 2003. Extraction of fat from fermented cupuaçu seeds with supercritical solvents. *The Journal of Supercritical Fluids* 27 (2):223–37. doi: 10.1016/S0896-8446(02)00240-1.

Azevedo, S. C. M., L. M. Vieira, T. Matsuura, G. F. D. Silva, S. Duvoisin, and P. M. Albuquerque. 2017. Estudo da conservação das propriedades nutricionais da polpa de tucumã (Astrocaryum aculeatum) in natura em embalagens a vácuo. *Brazilian Journal of Food Technology* 20: 1–9. doi: 10.1590/1981-6723.10716.

Balbi, M. E., P. T. P. S. Penteado, G. Cardoso, M. G. Sobral, and V. R. Souza. 2014. Castanha-do-pará (Bertholletia excelsa BONPL.): Composição química e sua importância para saúde. *Visão Acadêmica* 15 (2):51–63.

Bankoff, A. D. P., M. Arruda, and I. M. G. P. Bispo, M. P. Rodrigues. 2017. Doenças Crônicas não Transmissíveis: História familiar, hábitos alimentares e sedentarismo em alunos de graduação de ambos os sexos. *Revista Saúde e Meio Ambiente* 5 (2):37–56.

Barros, R. G. C., J. K. S. Andrade, M. Denadai, M. L. Nunes, and N. Narain. 2017. Evaluation of bioactive compounds potential and antioxidant activity in some Brazilian exotic fruit residues. *Food Research International* 102:84–92. doi: 10.1016/j.foodres.2017.09.082.

Bataglion, G. A., W. Henrique, A. A. X. Adrião, J. M. R. Albuquerque, F. M. A. Silva, I. A. N. Numa, and H. H. F. Koolen. 2020. Bioactive compounds of Buriti Fruit (Mauritia flexuosa Lf). In *Bioactive compounds in underutilized fruits and nuts*, eds. H. N. Murthy, and V. A. Bapat, 1–36. Cham: Springer.

Batista, A. G., A. S. Ferrari, D. C. Cunha, J. K. Silva, C. B. B. Cazarin, L. C. Correa, M. A. Prado, L. B. Carvalho-Silva, E. A. Esteves, and M. R. Maróstica Júnior. 2016. Polyphenols, antioxidants, and antimutagenic effects of *Copaifera langsdorffii* fruit. *Food Chemistry* 197: 1153–9. doi: 10.1016/j.foodchem.2015.11.093.

Batista, J. S., R. G. Olinda, V. B. Medeiros, C. M. F. Rodrigues, A. F. Oliveira, E. S. Paiva, C. I. A. Freitas, and A. C. Medeiros. 2012. Atividade antibacteriana e cicatrizante do óleo de buriti Mauritia flexuosa L. *Ciência Rural* 42 (1):136–41. doi: 10.1590/S0103-84782011005000155.

Bezerra, V. S. 2012. Considerações sobre a palmeira murumuruzeiro (Astrocaryum murumuru Mart.). Empresa Brasileira de Pesquisa Agropecuária - Embrapa. Accessed May 7, 2021. https://ainfo.cnptia.embrapa.br/digital/bitstream/item/84961/1/AP-2012-Comunicado-tecnico-130-Murumuru.pdf.

Bezerra, C. V., A. M. C. Rodrigues, P. D. Oliveira, D. A. Silva, and L. H. M. Silva. 2017. Technological properties of amazonian oil sand fats and their applications in the food industry. *Food Chemistry* 221: 1466–73. doi: 10.1016/j.foodchem.2016.11.004.

Brito, R. S., W. F. A. Alves, and J. G. V. Moreira. 2017. Avaliação do efeito da inibição da antracnose do maracujazeiro com a utilização do óleo de Pupunha (Bactrisgasipaes). *South American Journal of Basic Education, Technical and Technological* 4 (2):43–50.

Can-Cauich, C. A., E. Sauri-Duch, V. M. Moo-Huchin, D. Betancur-Ancona, and L. F. Cuevas-Glory. 2019. Effect of extraction method and specie on the content of bioactive compounds and antioxidant activity of pumpkin oil from Yucatan, Mexico. *Food Chemistry* 285: 186–93. doi: 10.1016/j.foodchem.2019.01.153.

Canuto, G. A. B., A. A. O. Xavier, L. C. Neves, and M. D. T. Benassi. 2010. Caracterização físico-química de polpas de frutos da Amazônia e sua correlação com a atividade anti-radical livre. *Revista Brasileira de Fruticultura* 32 (4):1196–205. doi: 10.1590/S0100-29452010005000122.

Carneiro, A. B. A., E. J. S. Pinto, I. F. Ribeiro, M. R. G. Magalhães, M. Neto, and M. B. Azevedo. 2017. Efeito da Astrocaryum aculeatum (Tucumã) na toxicidade da Doxorrubicina: Modelo experimental in vivo. *Acta Paulista de Enfermagem* 30 (3):233–239. doi: 10.1590/1982-0194201700036.

Cavalcanti, L. R. B. 2014. Castanha-do-brasil. Empresa Brasileira de Pesquisa Agropecuária - Embrapa. Accessed May 9, 2021. https://www.embrapa.br/busca-de-imagens/-/midia/1652001/castanha-do-brasil.

Cedrim, P. C. A. S., E. M. A. Barros, and T. G. Nascimento. 2018. Antioxidant properties of acai (Euterpeoleracea) in the metabolic syndrome. *Brazilian Journal of Food Technology* 21: e2017092. doi: 10.1590/1981-6723.09217.

Chunhieng, T., A. Hafidi, D. Pioch, J. Brochier, and M. Didier. 2008. Detailed study of Brazil nut (Bertholletia excelsa) oil micro-compounds: Phospholipids, tocopherols and sterols. *Journal of the Brazilian Chemical Society* 19 (7):1374–80. doi: 10.1590/S0103-50532008000700021.

Corrêa, A. P. L., R. R. C. Bastos, G. N. R. Filho, J. R. Zamian, and L. R. V. Conceição. 2020. Preparation of sulfonated carbon-based catalysts from murumuru kernel shell and their performance in the esterification reaction. *RSC Advances* 10 (34):20245–56. doi: 10.1039/D0RA03217D.

Costa, B. E. T., O. V. D. Santos, N. C. F. Corrêa, and L. F. D. França. 2016. Comparative study on the quality of oil extracted from two tucumã varieties using supercritical carbon dioxide. *Food Science and Technology* 36 (2):322–8. doi: 10.1590/1678-457X.0094.

Costa, M. N. F. S., M. A. P. Muniz, C. A. B. Negrão, C. E. F. Costa, M. L. N. Lamarão, L. Morais, J. O. C. Silva Júnior, and R. M. R. Costa. 2014. Characterization of Pentaclethra macroloba oil. *Journal of Thermal Analysis and Calorimetry* 115 (3):2269–75. doi: 10.1007/s10973-012-2896-z.

Costa, R. S. D., O. V. D. Santos, S. C. D. S. Lannes, A. A. Casazza, B. Aliakbarian, P. Perego, and J. O. C. Silva. 2020. Bioactive compounds and value-added applications of cupuassu (Theobroma grandiflorum Schum.) agroindustrial by-product. *Food Science and Technology* 40 (2):401–7. doi: 10.1590/fst.01119.

Costa, T., C. M. Veronezi, and N. Jorge. 2020. Chemical and bioactive properties of the oils from Brazilian nuts. *Scientia Agraria Paranaensis* 19 (2):180–6. doi: 10.18188/sap.v19i1.24152.

Criollo, J., D. Criollo, and A. S. Aldana. 2010. Fermentación de la almendra de copoazú (Theobromagrandiflorum [Willd. ex Spreng.] Schum). *Corpoica Ciencia y Tecnología Agropecuaria* 11 (2):107–15. doi: 10.21930/rcta.vol11_num2_art:200.

Cunha, V. M. B., M. P. Silva, S. H. B. Sousa, P. N. Bezerra, E. G. O. Menezes, N. J. N. Silva, and R. N. Carvalho Junior. 2019. Bacaba-de-leque (Oenocarpus distichus Mart.) oil extraction using supercritical CO2 and bioactive compounds determination in the residual pulp. *The Journal of Supercritical Fluids* 144:81–90. doi: 10.1016/j.supflu.2018.10.010.

Dabaja, M. Z., B. M. Bizzo, and E. B. Pereira. 2018. Síntese de biodiesel a partir do óleo de açaí empregando lipase comercial imobilizada em suporte de baixo custo. *Revista da Universidade Vale do Rio Verde* 16 (2):1–11. doi: 10.5892/ruvrd.v16i2.5016.

Dantas, A. R., L. C. Marangon, M. C. Guedes, A. L. P. Feliciano, and A. C. L. Guedes. 2017. Spatial distribution of a population of Pentaclethra macroloba (willd.) kuntze in a floodplain forest of the amazon estuary. *Rev. Árvore Viçosa* 41(4):1–11.

Darnet, S. H., L. H. M. Silva, A. M. C. Rodrigues, and R. T. Lins. 2011. Nutritional composition, fatty acid and tocopherol contents of buriti (Mauritia flexuosa) and patawa (Oenocarpus bataua) fruit pulp from the amazon region. *Ciência e Tecnologia de Alimentos* 31 (2):488–91. doi: 10.1590/S0101-20612011000200032.

Dima, C., and S. Dima. 2015. Essential oils in foods: Extraction, stabilization, and toxicity. *Current Opinion in Food Science* 5:29–35. doi: 10.1016/j.cofs.2015.07.003.

Diniz, M. B., M. J. T. Diniz, A. L. Ferreira, M. L. C. Barrios, and E. B. F. Lima. 2019. Região Amazônica: Biodiversidade E Possibilidades De Transformação Industrial. *Cadernos CEPEC* 6:1–6. doi: 10.18542/cepec.v6i1-6.7037.

Donsí, F., and G. Ferrari. 2016. Essential oil nanoemulsions as antimicrobial agents in food. *Journal of Biotechnology* 233:106–20. doi: 10.1016/j.jbiotec.2016.07.005.

Elisia, I., J. W. Young, Y. V. Yuan, and D. D. Kitts. 2013. Association between tocopherol isoform composition and lipid oxidation in selected multiple edible oils. *Food Research International* 52 (2): 508–14. doi: 10.1016/j.foodres.2013.02.013.

Fernandez, C. M. M., F. B. Lorenzetti, C. C. Iwanaga, K. Zanoli, L. P. S. Bernuci, J. P. P. Andrade, and B. P. Dias. 2021. Chemical composition and seasonal variation of the essential oils of leaves of Garcinia gardneriana (Planchon & Triana) Zappi (Clusiaceae).*Australian Journal of Crop Science* 15 (1):1–8. doi: 10.21475/ajcs.21.15.01.1800.

Ferreira, E. S., V. G. Lucien, A. S. Amaral, and C. S. Siqueira. 2008. Caracterização físico-química do fruto e do óleo extraído de tucumã (Astrocaryum vulgare Mart)*. *Alimentos e nutrição* 19 (4):427–33.

Ferreira, J. B., Y. Y. B. Neves, G. D. O. Nascimento, A. D. Figueiredo, and N. Venturin. 2012. Óleos essenciais no controle de

Colletotrichum gloeosporioides, agente causal da antracnose em palmáceas. *Enciclopédia Biosfera* 8 (14):751–60.

Ferreira, L. S., M. R. P. Santos, L. C. Figueira, K. M. R. Nagata, C. M. R. Remédios, and F. F. Sousa. 2017. Caracterização de óleos vegetais da Amazônia por espectroscopia de absorção. *Scientia Plena* 13 (1):1–7. doi: 10.14808/10.14808/sci.plena.2017.012704.

Ferreira, M. G. R., C. J. Costa, C. U. B. Pinheiro, E. R. B. Souza, and C. O. Carvalho. 2018. Mauritia flexuosa: Buriti. Accessed May 9, 2021. https://ainfo.cnptia.embrapa.br/digital/bitstream/item/190231/1/cap-buriti.pdf.

Franzini, V., A. Silva, D. D. S. Tavares, and J. Maciel. 2016. Resposta de mudas de tucumã à aplicação de doses de calcário e fósforo. *Embrapa Amazônia Oriental.* Artigo em periódico indexado (ALICE).

Freitas, S. P., O. F. Silva, I. C. D. Miranda, and M. A. S. Coelho. 2007. Extração e fracionamento simultâneo do óleo da castanha-do-Brasil com etanol. *Ciência e Tecnologia de Alimentos* 27:14–7. doi: 10.1590/S0101-20612007000500002.

Fuentes, V. M., L. A. Muehlmann, J. P. F. Longo, J. R. Silva, M. L. Fascineli, P. Souza, and C. M. Lucci. 2017. Photodynamic therapy mediated by acai oil (Euterpe oleracea Martius) in nanoemulsion: A potential treatment for melanoma. *Journal of Photochemistry and Photobiology B: Biology* 166:301–10. doi: 10.1016/j.jphotobiol.2016.12.002.

Garcia, R. F., and M. H. Yamaguchi. 2012. Óleo de copaíba e suas propriedades medicinais: Revisão bibliográfica. *Saúde e Pesquisa* 5(1): 137–46.

Girón, J. M., and L. E. O. Santos. 2016. Determinación de la concentración de pigmentos carotenoides en harina de residuos de chontaduro (Bactris gasipaes). *Producción + Limpia* 11 (1):85–93.

Gurgel, E. S. C., M. S. Oliveira, M. C. Souza, S. G. Silva, M. S. Mendonca, and A. P. S. Souza. 2019. Chemical compositions and herbicidal (phytotoxic) activity of essential oils of three Copaifera species (Leguminosae-Caesalpinoideae) from Amazon-Brazil. *Industrial Crops and Products* 142:111850. doi: 10.1016/j.indcrop.2019.111850.

Hernandez, I., L. Alegre, and S. Munné-Bosch. 2004. Drought-induced changes in flavonoids and other low molecular weight antioxidants in Cistus clusii grown under Mediterranean field conditions. *Tree Physiology* 24 (11):1303–11. doi: 10.1093/treephys/24.11.1303.

Hidalgo, P. S. P., R. C. S. Nunomura, and S. M. Nunomura. 2016. Plantas oleaginosas amazônicas: Química e atividade antioxidante de patauá (Oenocarpusbataua Mart.). *Revista Virtual de Química* 8 (1): 130–40. doi: 10.5935/1984-6835.20160009.

Homma, A. K. O., A. J. E. A. Menezes, J. E. U. Carvalho, and G. B. Matos. 2018. Manejo e plantio de bacurizeiros (Platoniainsignis Mart.): A experiência no manejo e domesticação de um recurso da biodiversidade amazônica. *Inclusão Social* 12 (1):48–57.

Homma, A. K. O., A. R. Alves, S. D. M. Alves, A. A. Franco, and H. W. A. Pena. 2012. *Environmental sustainable in agriculture and food security in the Brazilian Amazon. Embrapa Amazônia Oriental-Artigo em anais de congresso (ALICE).* In: Ecological Economics And Rio+ 20: Challenges And Contributions For A Green hoeconomy, 2012, Rio de Janeiro. Conference procedings. Rio de Janeiro: ISEE, 2012.

Jaramillo, J. E. C.C., M. P. C. Bautista, O. A. A. Solano, L. E. Achenie, and A. F. G. Barrios. 2019. Barrios. Impact of the Mode of Extraction on the Lipidomic Profile of Oils Obtained from Selected Amazonian Fruits. *Biomolecules* 9 (8):329. doi: 10.3390/biom9080329.

Junior, N. D. S. B. 2019. *Análise da estrutura da cadeia produtiva de óleos vegetais florestais: um estudo no estado do Pará, Amazônia Brasileira*.

Liaqat, I., N. Riaz, Q. U. Saleem, H. M. Tahir, M. Arshad, and N. Arshad. 2019. Toxicological Evaluation of Essential Oils from Some Plants of Rutaceae Family. *Evidence-Based Complementary and Alternative Medicine* 9:6–352.

Lima, M. C., and G. V. Portari. 2019. Composição centesimal e compostos antioxidantes de dois frutos do Cerrado brasileiro. *Ceres* 10(1).

Lima, R. P., P. T. S. Luz, M. Braga, P. R. S. Batista, C. E. F. Costa, J. R. Zamian, and G. N. Rocha Filho. 2017. Murumuru (Astrocaryummurumuru Mart.) butterandoilsof buriti (Mauritia flexuosa Mart.) andpracaxi (Pentaclethramacroloba (Willd.) Kuntze) can be used for biodiesel production: Physico-chemical properties and thermal and kinetic studies. *Industrial Crops and Products* 97: 536–44. doi: 10.1016/j.indcrop.2016.12.052.

Maestri, D., M. C. Cittadini, R. Bodoira, and M. Martínez. 2020. Tree nut oils: Chemical profiles, extraction, stability, and quality concerns. *European Journal of Lipid Science and Technology* 122 (6): 1900450. doi: 10.1002/ejlt.201900450.

Magrach, A., and M. J. Sanz. 2020. Environmental and social consequences of the increase in the demand for ‘superfoods’ world-wide. *People and Nature* 2 (2):267–78. doi: 10.1002/pan3.10085.

Marangon, C. A., P. M. F. Leite, M. A. V. Rodrigues, V. C. A. Martins, A. M. G. Plepis, and M. Nitschke. 2016. *Influência dos óleos de copaíba e buriti em emulsões de quitosana/gelatina sobre Staphylococcus aureus*. In: Anais. Foz do Iguaçu.

Marques, E. D. S., J. G. Froder, P. R. D. Oliveira, F. F. Perazzo, P. C. P. Rosa, I. O. Gaivão, and E. L. Maistro. 2019. Cytotoxic effects of Euterpe oleraceae fruit oil (açaí) in rat liver and thyroid tissues. *Revista Brasileira de Farmacognosia* 29 (1):54–61. doi: 10.1016/j.bjp.2018.12.001.

Marques, H. P., S. Barbosa, D. A. Nogueira, M. H. Santos, B. R. Santos, and P. R. Santos-Filho. 2018. Proteic and phenolics compounds contents in Bacupari callus cultured with glutamine and nitrogen sources. *Brazilian Journal of Biology = Revista Brasleira de Biologia* 78 (1):41–6. doi: 10.1590/1519-6984.03416.

Marronato, A., T. S. Almeida, J. P. Mota, C. A. Oliveira, C. Rosado, and M. V. R. Velasco. 2016. Comparison of sunscreens containing titanium dioxide alone or in association with cocoa, Murumuru Or Cupuaçu Butters. *Journal Biomedical and Biopharmaceutical Research* 13 (2):229–44. doi: 10.19277/bbr.13.2.141.

Martins, Q. S., L. M. S. Santos, and J. L. B. Faria. 2020. Raman spectra and ab-initio calculations in Bertholletia excelsa oil. *Vibrational Spectroscopy* 106:102986. doi: 10.1016/j.vibspec.2019.102986.

Meneguetti, N. F. S. P., and A. Siviero. 2019. Potencial biotecnológico de espécies vegetais oleaginosas ocorrentes em comunidades extrativistas do Acre. *Embrapa Acre-Capítulo em livro técnico* (INFOTECA-E). In: A. Siviero, R. C. dos Santos, E. P. L. Mattar (Org.). Conservação e tecnologias para o desenvolvimento agrícola e florestal no Acre. Rio Branco, AC: Ifac, 2019.Cap. 4, p. 115–146.

Milanez, J. T., L. C. Neves, R. C. Colombo, M. Shahab, and S. R. Roberto. 2018. Bioactive compounds and antioxidant activity of buriti fruits, during the postharvest, harvested at different ripening stages. *Scientia Horticulturae* 227:10–21. doi: 10.1016/j.scienta.2017.08.045.

Mosquera, D. M., J. E. Cardona, R. H. Gutiérrez, and M. S. Hernández. 2012. Obtención de aceites vegetales provenientes de especies Amazónicas mediante la técnica de extracción asistida por microondas (EAM). *Vitae* 19 (1):S57–S59.

Moura, C. V. R., B. C. Silva, A. G. Castro, E. M. Moura, M. D. C. Veloso, I. M. Sittolin, and E. C. E. Araujo. 2019. Caracterização físico-química de óleos vegetais de oleaginosas adaptáveis ao Nordeste Brasileiro com potenciais para produção de biodiesel. *Revista Virtual de Química* 11 (3):573–95. doi: 10.21577/1984-6835.20190044.

Nascimento, R. J. S. D., S. Couri, R. Antoniassi, and S. P. Freitas. 2008. Fatty acids composition of açaí pulp oil obtained by enzymatic technology and hexane. *Revista Brasileira de Fruticultura* 30 (2):498–502. doi: 10.1590/S0100-29452008000200040.

Negri, T. C., P. R. A. Berni, and S. G. C. Brazaca. 2016. Valor nutricional de frutas nativas e exóticas do Brasil. *Biosaúde* 18 (2):82–96.

Oliveira, P. D., L. A. Araujo, L. H. Silva, and A. M. Rodrigues. 2016. Predicting temperature-dependent viscosity of amazonian vegetable oils and their mixtures from fatty acid composition. *International Journal of Food Properties* 19 (9):1972–82. doi: 10.1080/10942912.2015.1090448.

Oliveira, W. S., J. A. M. Silva, and C. A. M. Rocha. 2019. Prospecção Científica e Tecnológica da Utilização do Óleo de Pracaxi. *Cadernos de Prospecção* 12 (5)1560–1571.

Pardauil, J. J., F. A. Molfetta, M. Braga, L. K. Souza, N. R. Geraldo Filho, J. R. Zamian, and C. E. F. Costa. 2017. Characterization, termal properties and phase transitions of amazonian vegetable oils. *Journal of Thermal Analysis and Calorimetry* 127 (2):1221–9. doi: 10.1007/s10973-016-5605-5.

Pereira, E., M. C. Ferreira, K. A. Sampaio, R. Grimaldi, A. J. A. Meirelles, and G. J. Maximo. 2019. Physical properties of Amazonian fats and oils and their blends. *Food Chemistry* 278: 208–15. doi: 10.1016/j.foodchem.2018.11.016.

Pereira, Y. F., M. S. Costa, S. R. Tintino, J. E. Rocha, F. F. G. Rodrigues, M. K. S. B. Feitosa, and E. O. Sousa. 2018. Modulation of the Antibiotic Activity by the Mauritiaflexuosa (Buriti) Fixed Oil against Methicillin-Resistant Staphylococcus Aureus (MRSA) and Other Multidrug-Resistant (MDR) Bacterial Strains. *Pathogens* 7 (4):98.

Restrepo, J., J. A. Estupinan, and A. J. Colmenares. 2016. Estudio comparativo de las fracciones lipídicas de Bactrisgasipaes Kunth (chontaduro) obtenidas por extracción soxhlet y por extracciόncon CO2 supercrítico. *Revista Colombiana de Química* 45 (1):5–9. doi: 10.15446/rev.colomb.quim.v45n1.57199.

Rezende, A. A., G. M. P. Melo, L. M. A. Bertipaglia, and W. J. Melo. 2020. Avaliação in vitro de óleos essenciais de copaíba, buriti e tucumã para controlar Sthapylococcus aureus. Produção e Controle de Produtos Naturais 2. In *Produção e controle de produtos naturais 2.* ed. R. R. S. Silva-Matos, V. R. Cardoso, K. V. Cordeiro, 26–38. Ponta Grossa, Brazil: *Editora Atena.*

Rufino, M. S. M., J. P. Jiménez, S. Arranz, R. E. Alves, E. S. Brito, M. S. Oliveira, and F. Saura-Calixto. 2011. Açaí (Euterpe oleraceae) 'BRS Pará': A tropical fruit source of antioxidant dietary fiber and high antioxidant capacity oil. *Food Research International* 44 (7): 2100–6. doi: 10.1016/j.foodres.2010.09.011.

Santos, D. D. S., V. Klauck, G. Campigotto, D. F. Alba, J. H. Reis, R. R. Gebert, and R. Wagner. 2019. Benefits of the inclusion of açai oil in the diet of dairy sheep in heat stress on health and milk production and quality. *Journal of Thermal Biology* 84:250–8. doi: 10.1016/j.jtherbio.2019.07.007.

Santos, F. D. R. P., M. G. B. Santos, V. B. Lucena, and J. A. Chaves. 2021. Características físico-químicas de um sérum desenvolvido à base do óleo de buriti (Mauritia flexuosa) para pele idosa. *Revista Enfermagem Atual in Derme* 95 (33):1–15.

Santos, M. D. F. G. D., R. E. Alves, E. S. D. Brito, S. D. M. Silva, and M. R. S. D. Silveira. 2017. Quality characteristis of fruits and oils of palms native to the Brazilian Amazon. *Revista Brasileira de Fruticultura* 39: 1–6.

Santos, M. M. R., D. S. Fernandes, C. J. Cândido, L. F. Cavalheiro, A. F. Silva, V. A. Nascimento, and P. A. Hiane. 2018. Physical-chemical, nutrition aland antioxidante properties of tucumã. (Astrocaryumhuaimi Mart.) Fruits. *Semina: Ciências Agrárias* 39 (4):1517–31.

Santos, O. V. D., S. D. Soares, P. C. S. Dias, S. D. P. D. A. Duarte, M. P. L. D. Santos, and F. D. C. A. D. Nascimento. 2020. Chromatographic profile and bioactive compounds found in the composition of pupunha oil (Bactris gasipaes Kunth): implications for human health. *Revista de Nutrição* 33: 1–12. doi: 10.1590/1678-9805202033e190146.

Santos, O. V., J. R. R. N. Carvalho, C. E. F. Costa, and S. C. S. Lannes. 2019. Chemical, chromatographic-functional, thermogravimetric-differential and spectroscopic parameters of the sapucaia oil obtained by different extraction methods. *Industrial Crops and Products* 132: 487–96. doi: 10.1016/j.indcrop.2019.02.043.

Santos, R. C., A. A. Melo Filho, E. A. Chagas, J. A. Takahashi, I. F. Monteiro, L. C. Holanda, and A. C. G. R. Melo. 2018. Chemical characterization of oils and fats from amazonian fruits by 1H NMR. *Chemical Engineering Transactions* 68: 235–240.

Saxena, A., L. Sharma, and T. Maity. 2020. Enrichment of edible coatings and films with plant extracts or essential oils for the preservation of fruits and vegetables. In *Biopolymer-Based Formulations*, ed. K. Pal, I. Banerjee, P. Sarkar, D. Kim, W.-P. Deng, N. K. Dubey, K. Majumder, 859–80. Elsevier.

Schneider, L. C., K. V. Leão, L. L. Machado, and A. R. D. Guimarães. 2020. Physical and chemical characterization of bacupari. fruits, Salacia Crassifolia (Mart. ExSchult.) G. Don, from the municipality of Barreiras–BA. *Brazilian Journal of Development*. 6 (3):13942–53.

Seow, Y. X., C. R. Yeo, H. L. Chung, and H. G. Yuk. 2014. Plant essential oils as active antimicrobial agents. *Critical Reviews in Food Science and Nutrition* 54 (5):625–44. doi: 10.1080/10408398.2011.599504.

Serra, J. L., A. M. C. Rodrigues, R. A. Freitas, A. J. A. Meirelles, S. H. Darnet, and L. H. M. Silva. 2019. Alternative sources of oils and fats from Amazonian plants: Fatty acids, methyl tocols, total carotenoids and chemical composition. *Food Research International* 116:12–9. doi: 10.1016/j.foodres.2018.12.028.

Silva, A. G., P. F. Puziol, R. N. Leitão, T. R. Gomes, R. Scherer, M. L. L. Martins, and L. C. Cavalcanti. 2012. Application of the Essential Oil from Copaiba (Copaifera langsdorffii Desf.) for Acne Vulgaris: a Double-Blind, Placebo Controlled Clinical Trial. *Alternative Medicine Review* 17 (1):69–75.

Silva, A. J., L. P. Oliveira, J. C. D. P. Rezende, and I. S. Saraiva. 2019. Avaliação da atividade antimicrobiana de óleos essenciais obtidos de diferentes fabricantes. *Sinapse Múltipla* 8 (1):33–40.

Silva, D. C. F., F. L. A. Carvalho, G. P. S. Maciel, G. C. Castro, L. S. Borges, L. S. Sena, and R. C. Moura. 2020. Óleo de buriti como alternativa aos antibióticos melhoradores de desempenho em dietas para frangos de corte. In *Estudos em zootecnia e ciência animal 2,* ed. G. Krahl, 83–94. Ponta Grossa, Brazil: *Editora Atena.* .

Silva, E. P. O., L. H. Castro, R. M. Bianggio, and M. Beltrane Júnior. 2010. Estudo das características físico-químicas e classificação de fitoingredientes na espécie Astrocaryum murumuru (murumuru). In: Encontro Latino Americano de Iniciação científica. São José dos Campos. *Biodiversidade: conservação, Preservação e Recuperação* 12 (8):1–3.

Silva, J. L., and M. F. B. Durigan. 2018. Valorização e uso popular do óleo de pracaxi [Pentaclethra macroloba (Willd.) Kuntze]. Empresa Brasileira de Pesquisa Agropecuária - Embrapa. Available in: https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1104243/1/FOLDERpracaxiSimpAgro20182.pdf. Access in: 09 may 2021.

Singh, T. C., and N. Jorge. 2013. *Perfil de ácidos graxos de óleos extraídos da polpa de pupunha (Bactris gasipaes Kunth). Anais do Simpósio Latino Americano de Ciências de Alimentos*. Campinas, Galoá.

Souza, A. G. C., and M. G. Souza. 2018. Enxertia de borbulhia em placa em cupuaçuzeiro. Embrapa Amazônia Ocidental. Accessed May 9, 2021. https://ainfo.cnptia.embrapa.br/digital/bitstream/item/184581/1/122018-Final.pdf.

Souza, B. F. F., H. O. Carvalho, I. M. Ferreira, E. L. Cunha, A. S. Barros, T. Taglialegna, and J. C. T. Carvalho. 2017. Effect of the treatment with Euterpe oleracea Mart. oil in rats with Triton-induced dyslipidemia. *Biomedicine & Pharmacotherapy* 90:542–7. doi: 10.1016/j.biopha.2017.04.005.

Speranza, P., A. O. Falcão, J. A. Macedo, L. H. M. Silva, A. M. C. Rodrigues, and G. A. Macedo. 2016. Amazonian Buriti oil: Chemical characterization and antioxidant potential.: Chemical characterization and antioxidant potential. *Grasas y Aceites* 67 (2):e135. doi: 10.3989/gya.0622152.

Stupp, T., R. A. Freitas, M. R. Sierakowski, F. C. Deschamps, A. Wisniewski, and M. W. Biavatti. 2008. Characterization and potential uses of Copaifera langsdorfii seeds and seed oil. *Bioresource Technology* 99 (7):2659–63.

Teixeira, G. L., L. G. Maciel, S. Mazzutti, C. B. Gonçalves, S. R. S. Ferreira, and J. M. Block. 2020. Composition, thermal behavior and antioxidant activity of pracaxi (Pentaclethra macroloba) seed oil obtained by supercritical CO2. *Biocatalysis and Agricultural Biotechnology* 24:101521. doi: 10.1016/j.bcab.2020.101521.

Teixeira, G. L., S. M. Ghazani, M. L. Corazza, A. G. Marangoni, and R. H. Ribani. 2018. Assessment of subcritical propane, supercritical CO2 and Soxhlet extraction of oil from sapucaia (Lecythis pisonis) nuts. *The Journal of Supercritical Fluids* 133:122–32. doi: 10.1016/j.supflu.2017.10.003.

Urasaki, Y., C. Beaumont, M. Workman, J. N. Talbot, D. K. Hill, and T. T. Le. 2020. Fast-Acting and Receptor-Mediated Regulation of Neuronal Signaling Pathways by Copaiba Essential Oil. *International*

Journal of Molecular Sciences 21 (7):2259. doi: 10.3390/ijms21072259.

Veiga, V. V., E. C. Rosas, M. V. D. Carvalho, M. Henriques, and A. C. Pinto. 2007. Chemical composition and anti-inflammatory activity of copaiba oils from Copaifera cearensis Huber ex Ducke, Copaifera reticulata Ducke and Copaifera multijuga Hayne—A comparative study. *Journal of Ethnopharmacology* 112 (2):248–254. doi: 10.1016/j.jep.2007.03.005.

Vilhena, A. E. G., R. L. C. Sehwartz, P. T. S. Bezerra, and D. D. S. B. Brasil. 2020. Physical and chemical characterization of Pará chestnut oil extracted by hydraulic pressing. *Brazilian Applied Science Review* 4 (3):859–865. doi: 10.34115/basrv4n3-009.

Villela, A. A., B. J. D'Alembert, L. P. Rosa, and M. V. Freitas. 2014. Status and prospects of oil palm in the Brazilian Amazon. *Biomass and Bioenergy* 67:270–278. doi: 10.1016/j.biombioe.2014.05.005.

Willerding, A. L., F. G. M. R. Carvalho Neto, A. M. Gama, and C. R. F. Carioca. 2012. Hydrolytic activity of bacterial lipases in Amazonian vegetable oils. *Química Nova* 35 (9):1782–1786. doi: 10.1590/S0100-40422012000900015.

World of Oils.2020. Aceite de Copaíba: conocido como "Aceite de la Vida". Accessed May 9, 2021. http://mundodosoleos.com/blogs/news/oleo-de-copaiba-oleo-da-vida?lang=es.

Yun, J., C. Wu, X. Li, and X. Fan. 2018. Improving the microbial food safety of fresh fruits and vegetables with aqueous and vaporous essential oils. In *Natural and Bio-Based Antimicrobials for Food Applications*, ed. X. Fan, H. Ngo, and C. Wu, 87–117. Washingto DC: American Chemical Society.

Yuyama, L. K. O., R. N. Maeda, L. Pantoja, J. P. L. Aguiar, and H. A. Marinho. 2008. Processamento e avaliação da vida de prateleira do tucumã (Astrocaryumaculeatum Meyer) desidratado e pulverizado. *Ciência e Tecnologia de Alimentos* 28 (2):408–412. doi: 10.1590/S0101-20612008000200021.