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Characteristics and Effects of the Amazonian Andiroba (*Carapa guianensis* Aubl.) Oil Against Living Organisms – A Review

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Abstract:
The andiroba (Carapa guianensis Aubl.) tree is a native Meliaceae family species from the Amazon region that has an important socioeconomic function due to its (wood / bark / leaf / seeds) several applications for the indigenous population. Its seed has one of the most healing oils known in that region. The andiroba oil (AO) applications vary from anti-living organisms (bacteria / fungi / insect / parasite) attack, to diseases (itching / fever / asthma / sore throat /wound) symptoms healing / cure. This review gathers literature information regarding AO characteristics related to tree and seed botany, oil extraction procedures, sensory specifics, physical and chemical composition, apart from its effects against different living organisms and their susceptibilities. Also, information regarding its health and food applications, including possible toxicity and seed residues utilization.

Key Word*:Andiroba; Oil; Decontamination; Fungi; Food; Amazon.*

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I. Introduction

The Amazonian forest (Central America and Northern part of South America) is a source of a quite broad diversity of native plants that have multiple applications, especially the trees. Among them, there is the *Carapa guianensis* Aubl, known throughout the Amazon region as *Andirobeira* (Pennington et al., 1981; Fisch et al., 1995). The *andiroba* term, in Brazil, is derived from the Tupi-Guarani (indigenous language) word *iand* that means oil, and *rob* for bitter (Silva et al., 2005).

Thus, *andiroba* means bitter oil, a flavor conferred to the high level of phenolic compounds, which apart from the seeds, are also reported in the branches and trunks (da Silva et al., 2009). It is also called, *andirobinha,iandiroba*, *andiroba branca, andiroba-do-igapó, carape, jandiroba*and*penaiba*in Brazil. On the other hand, in different languages / countries it is called *roba-mahogany* (United States of America), *karapa, british-guiana-mahogany* (Guiana), *bois-caille, carape-blanc, carape-rouge, andiroba-carapa* (French Guiana), *crabwood* (England), *cedro-bateo*(Panama), *andiroba* (Paraguay / Uruguay), *krappa* (Suriname) and *cedro macho* (Cuba) (Horn, 1918, Gerry et al., 1957, Kukachka, 1962, Andrade et al., 2001, Ferrari et al., 2007; Barros et al., 2012).

Its wood is of high quality, either for housing construction, furniture manufacturing and vessels interior. The bark, leaves, flowers and seeds can also be used for tea and oil extraction for different treatment applications (Hammer & Johns, 1993; Andrade, 2001; Silva, 2002; Ambrozin et al., 2006; Farias, 2007; Mendonca &Ferraz, 2007; Tappin, 2007; Andrade, 2008; Tappin et al., 2008; Pessoa, 2009; Chicaro, 2010; Gomes, 2010; Miranda, 2010; Barros, 2011; Tanaka et al., 2012). Despite that, the seeds oil (*andiroba* oil – AO) is the most known and utilized by the indigenous groups and other natives for a quite broad healing applications either for disease symptoms healing (snake bites/insect stings & repellent, microorganisms – bacteria / fungi infection) and other living organisms (protozoa, parasites) (Silva, 2002;Silva et al., 2009; Gomes, 2010; Lima, 2009; Miranda et al., 2012). The oil can also be applied in the manufacture of soaps and repellent candles.

This review gathers information on AO characteristics (tree botany / physical-chemical / sensorial / composition) regarding its effect against living organisms and its applications.

II. The Andiroba Tree

- **Botany**

The species *Carapa guianensis* Aubl., Sapindales order, *Carapa* genus belongs to the Meliaceae family (alternate pinnate leaves, no stipules with flowers borne in panicles, cymes, spikes or clusters) (Barros et al., 2012). It is a monoecious tree of medium to large size with cylindrical and straight trunk. It can reach up to 55 m in height, (usually reaching 25-35 m). It has a cylindrical and straight shaft of 20-30 m, and may present sapopemas (flat roots). Its crown is of medium size, dense and composed of erect branches or with a slight

curvature. Its bark is thick and bitter and has a reddish color, but it can also be grayish (Ferraz et al., 2003). Figure 1 shows *andiroba* tree characteristics.

The branches (30-90 cm in length) tend to stand upright, with large leaves (composed, alternated and paripinate), with a trace of a terminal, tomentose and glandular leaflet (Ferraz et al., 2002). Opposite or subopposite leaflets of 3-10 pairs, 10-50 cm long and 4-18 cm wide. They have full margins and a shiny dark green collor on the upper surface and glabrous on the lower surface with simple and sparse trichomes in the central vein. Also present extra-floral nectaries at the leaf tips (Lorenzi, 1992;Ferraz et al., 2003).

Figure 1. Andiroba (*Carapa guianensis Aubl.*):(a) seed germination parts and (b) adult tree (Ferraz et al., 2003 and current authors, respectively).

Its flowers are small (Figure 2), with petals no more than 8 mm long, unisexual, sessile or sub-sessile, glabrous, slightly fragrant white to cream and are predominantly 4-mere, with 4 sepals, 8 petals and 16 stamens (Rizzini& Mors, 1976; Pennington et al.,1981). The *andiroba* tree flowering occurs during the *rain* season (from January-February to August-September) and *dry* season with fruiting between autumn (from June-July to February-March). Its fructification starts 10 years after planting (Ferraz et al., 2003; Lima, 2010).

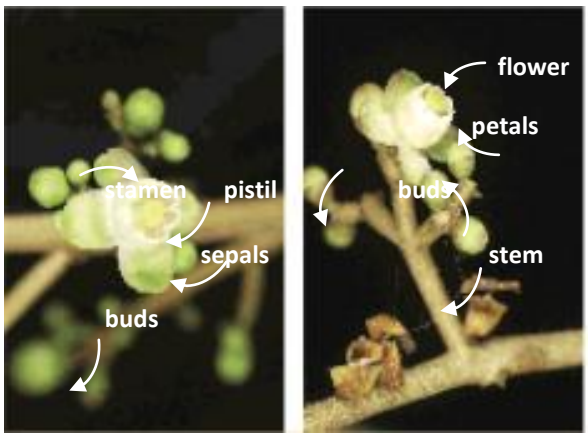


Figure 2. Details of the andiroba (*Carapa guianensis* Aubl.) flower (Embrapa-modified).

The fruit (Figure 3) is a capsule, formed of 4 valves, globous or subglobous (5-11 cm diameter), when ripe opens and releases from 4 to 12 seeds (Loureiro et al.,1979; Pennington et al.,1981; Cavalcante, 1991; Lorenzi, 1992, Prophiro et al., 2012). It is dark yellow in color, weighing 90 and 540 g for shell and seeds respectively (corresponding to 24 and 66% of the total fruit) (D'Alessandro; 2008).

The *andiroba* seed, which provides large amounts of oil, has a brown color, with rather large variation in shape and size. Their weight can vary from 1 to 70 g (average 21 g) and length from 10 to 60 mm (Ferraz et al., 2003). Its sides are angled due to seeds mutual compression (in the pod). Its tree can produce from 180 to 200 kg / year of seeds containing approximately 60% of AO (Lorenzi, 1992).

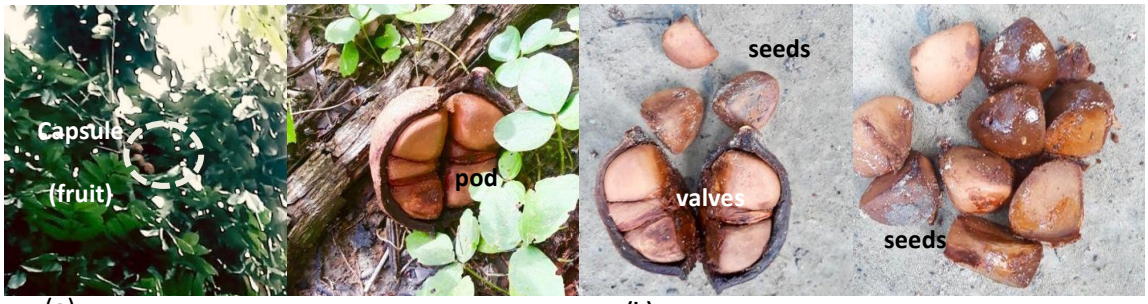


Figure 3. Andiroba (*Carapa guianensis* Aubl) characteristics of the: (a) fruit and (b) seeds (their distribution in the pod).

- **Distribution and climate**

The native species are distributed from Central America to the Northern region of South America (British and French Guiana, Trinidad, along the Caribbean Coast, Venezuela, Ecuador, Colombia, Peru and Brazil). Apart from those countries, andiroba is also found in West India and South Africa (Ferraz& Camargo, 2003, Qi et al., 2003, Qi et al., 2004, Ambrozin et al., 2006, Duminil et al., 2006, Farias et al., 2007, Ferrari et al., 2007).

In Brazil, it occurs in the Northern (Acre, Amazonas, Amapá and Pará) and Northeast (Maranhão) regions (Sakuragui et al., 2012). It is found manly in floodplains and swamps along the water streams. Although, it also grows on hillsides in well-drained soils and is widely cultivated on land, where it reaches smaller size (Lima & Azevedo, 2005).

Regarding climate, andiroba trees occur in regions with humid tropical climate (precipitations between 1,800 and 3,500 mm annually). Temperatures can range 17 to 30°C and relative humidity from 70 to 90%. The species is best developed in clay and muddy soils (not soaked) and abundant organic matter (Revilla, 2001).

III. Andiroba oil

Throughout the history of the Amazon, AO has played an important role in the regional economy and continues to be highly appreciated, especially in popular medicine. Compared to logging, the collection of seeds requires little investment and is not tree destructive. AO production can ensure an annual economic return for the local population. Oil and its by-products, such as soaps and candles, are generally found at street markets.

- **Oil extraction**

The AO can be extracted both by *traditional* (small portions) and *commercial* (large scale) procedures / processes. The Figure 4 summarizes the extraction steps of the *traditional* and *commercial* method.

Traditional:this extraction method is quiet utilized by the natives (indigenous communities and *caboclas* of the Northern Region), where it is divided into: seed collection & selection, mass preparation and oil extraction (Mendonca &Ferraz, 2007). It consists of boiling the seeds in water (2-3 h), then leaving them to rest (in the shade / few days) (Figure 4.a). After that period of time, the seeds are peeled and crushed in a pestle. When this material is totally crushed, it is sun exposed that gradually releases the oil by dripping. The yield of the traditional process in estimated of 4% of total seed (40 g of oil / kg). From the oil extraction, the remaining seed meal can be utilized for insects repellant (candles) (Ferraz&Carmargo, 2003; Embrapa-Acre, 2002).

Commercial / industrial:the process starts from break the seeds into small pieces, then drying in an oven at 60-70°C until reaching 8% moisture content (mc) followed by pressing (at 90°C) in hydraulic presses. The double-pressed industrial yield rarely exceeds 30% of the weight of the seeds (with 8% mc) (Ferraz& Camargo, 2003; EMBRAPA Acre, 2002).

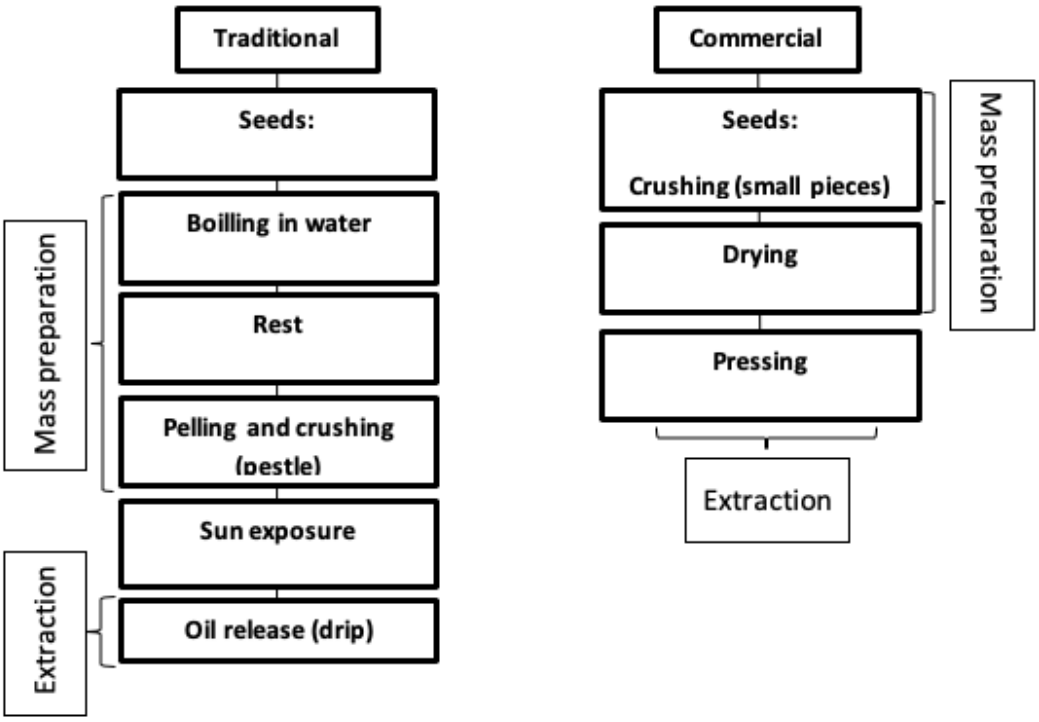


Figure 4. Flowchart of the (a) Traditional and (b) Commercial extraction processes of andiroba (*Carapa guianensis* Aubl.) oil.

- **Physicochemical properties and sensory characteristics**

The AO extracted from the andiroba seed is light yellow and has a very bitter taste (Figure 5). When subjected to temperatures below 25°C, it solidifies, acquiring a consistency similar to that of petroleum jelly (Farias, 2007, Menezes, 2008). After extraction, it quickly becomes profitable (Andrade, 2008; Gomes, 2010).

Figure 5. Andiroba (*Carapa guianensis* Aubl.) oil extracted from seeds.

The oil can also be dark and fast flowing, when extracted from species that occur on dry land, or light and viscous, when extracted from species that occur in lowland areas (Senhorini, 2010).

Table 1 shows the oil physical-chemical properties.As physical characteristics, andiroba oil has a viscosity of 46.6 mm^2s^{-1} and a density of 0.92 gr ltr^{-1}. With respect tochemical parameters, the oil has an iodine index ranging from 65 to 75 g of I_2g^{-1}, a acidity level of 2.3 mg KOH g^{-1}, a refractive index of 1,459, in addition to 7.13 h of Oxidativestability, PetroOxy, saponification index between 190 to 210 mg KOH g^{-1}, fusion point of 22 ^oC and unsaponifiable matter 3 to 5%.Seeds contain lipids, fiber, minerals and fatty acids. According to the

following composition in the oil: Moisture, Protein, Lipid, Crude Fiber, ash and Carbohydrates of 40.2, 6.2, 33.9, 12.0, 1.8 and 6.1% (Melo et al., 2008; Pinto, 2007).

Table 1. Physicochemical properties of the andiroba (*Carapa guianensis* Aubl.) oil.

Parameter		
Physical	**Values**	**Unit**
Viscosity	46.6	$mm^2\ s^{-1}$
Density 15 °C	0.92	$gr\ ltr^{-1}$
Chemical		
Iodine index	65 - 75	g of $I_2\ g^{-1}$
Acidity level	2.30	mg KOH g^{-1}
Refractive index	1.459	
Oxidativestability, PetroOxy	7.13	h
Saponification index	190 - 210	mg KOH g^{-1}
Fusion point	22.0	°C
Unsaponifiable matter	3 - 5	%
Proximate Composition		
Moisture	40.2	%
Protein	6.2	%
Lipid	33.9	%
Crude Fiber	12.0	%
Ash	1.8	%
Carbohydrates	6.1	%

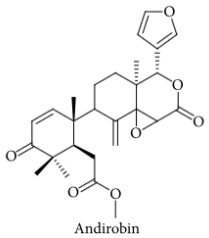
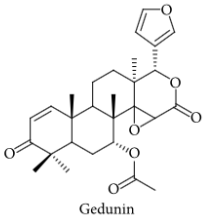
Melo et al., 2008, Pinto, 2007.

- **Chemical Composition**

Regarding the AO composition (Table 2), several compounds present in this species are reported. Among them, andirobin, gedunine and its derivatives known as 7-deacetoxy-7-oxogedunine, 6α-acetoxygedunine, 11β-acetoxygedunine, 6α, 11β-acetoxygedunine, 6α-hydroxygedunine, 6β, 11βdiacetoxygedunine, 1,2-dihydro-3β-hydroxy-7-deacetoxy-7-oxo-gedunine, α-acetoxygedunine, β-acetoxygedunine and dihydrogedunine (Marcelle &Mootoo, 1975; Hammer & Johns, 1993; Andrade et al., 2001; Sarria et al., 2011; Tanaka et al., 2011; Arrebola et al., 2012; Inoue et al., 2012).

Other components are also present of 6α-acetoxy-epoxiazadiradione, 1,3-di-benzene carbo amino-2-octadecyl acyl-glyceride, triacontanoic acid, 2,6-dihydroxy-methyl-benzoate, 3,4-dihydroxy-methyl-benzoate, tetratriacontanoic acid, naringenin, scopoletina, 2,3-dihydroxy-glyceride hexacosanoic acid, epoxy-azadiradione, methyl angolensate, 4-epoxiazadiradione, methyl angolensatedin, 4,4,8-trimethyl-17-furanylsteroid, carapanolides limonoids A and B, 3β-deacetylfissinolideo, ocotilloneo, β-photogedunine, cabraleadiol, α-dihydroxyiterpene, α-11-β-trihydroxyiterpene and 6β-acetoxygedunine (Andrade et al., 2001; Sarria et al., 2011; Tanaka et al., 2011; Arrebola et al., 2012; Inoue et al., 2012).

Table 2. Andiroba (*Carapa guianensis* Aubl) oil composition regarding andirobin and gedunine derivatives and other components.

Andirobin and gedunine AO composition	**Others**
Andirobin  Andirobin	α-dihydroxyiterpene
Gedunine  Gedunin	α-11-β-trihydroxyiterpene
7-deacetoxy-7-oxogedunine 6α-acetoxygedunine	6α-acetoxy-epoxiazadiradione triacontanoic acid

11β-acetoxygedunine	2,6-dihydroxy-methyl-benzoate
6α, 11β-acetoxygedunine	3,4-dihydroxy-methyl-benzoate
6α-hydroxygedunine	tetratriacontanoic acid
6β, 11β-diacetoxigedunine	cabraleadiol
1,2-dihydro-3β-hydroxy-7-deacetoxy-7-oxo-gedunine	2,3-dihydroxy-glyceride hexacosanoic acid
β-acetoxygedunine	scopoletina
dihydrogedunine	3β-deacetylfissinolideo
6β-acetoxygedunine	epoxy-azadiradione
α-acetoxygedunine	methyl angolensate
β-photogedunine	4-epoxiazadiradione
	methyl angolensatedin
	4,4,8-trimethyl-17-furanylsteroid
	carapanolides limonoids A and B
	naringenin
	ocotilloneo
	1,3-di-benzene carbo amino-2-octadecyl acyl-glyceride

Andiroba oil consists of fatty acids and an unsaponifiable fraction (2 to 5%). This is composed of bitter substances, called meliacins or limonoids (Ambrozim, 2000; Ambrozim et al., 2006).

The presence of oleic, palmitic, stearic, arachidic, myristic and linoleic acids has been reported, in addition to α-cubelene, α-copaene, ethyl palmitate, karyophylene, α-karyophylene, olein, palmitine and glycerin (Diniz et al., 2005; Penido et al., 2005; Penido et al., 2006;Costa-Silva et al., 2007; Costa-Silva et al., 2008; Carvalho et al., 2012; Souza et al., 2012).

Among the fatty acids present in AO (Table 3), oleic acid (46.8-52%) and palmitic acid (28-39%) are the major compounds. Other fatty acids were also quantified, such as stearic acid (1.7-7.8%), α-cubelene (0.5%), α-copaene (2.3%), arachidic acid (1.2%) and ethyl palmitate 0.9% in small / lower percentage though (Penido et al., 2005; Penido et al., 2006; Costa-Silva et al., 2007; Costa-Silva et al., 2008; Souza et al., 2012).

Table 3. Andiroba (*Carapa guianensis* Aubl.) oil fatty acids composition

Composition of fatty acids	
Fatty acids	**Composition (%)**
Saturated	
Myristic	0.33
Palmitic	28 – 39
Stearic	1.7 – 7.8
Ethyl palmitate	0.9
Unsaturated	
Oleic	46.8 – 52
Linoleic	11.03
Linolenic	1.35
Archaic	1.2
α-cubelene	0.5
α-copaene	2.3
Behenic	0.34

The bitterness of andiroba oil is attributed to a group of terpenes called meliacins, which are very similar to bitter antimalarial chemicals. Recently, one of these meliacins, called gedunine, has been documented with antiparasitic and antimalarial properties with an effect similar to quinine (Mackinnon et al., 2002). Chemical analysis of andiroba oil identified the anti-inflammatory, healing and insect-repellent properties that are attributed to the presence of limonoids, named andirobin (Roy & Saraf, 2006). Limonoids are the compounds responsible for the antiseptic, anti-inflammatory, healing and insecticidal activity of oil and bark of andiroba (Barros, 2011).

In the unsaponifiable fraction (Table 4) glyceride 1,3-di-benzene carbonamine-2-octadecylic acid, 2,6-dihydroxymethylbenzoate, 3,4-dihydroxymethylbenzoate, naringenin, tetratriacontanoic acid, triacontanoic acid, ursolic acid, scopoletina, 2,3-dihydroxy-glyceride hexacosanoic acid, 6α-acetoxiepoxiazadiradione, 6α-hydroxygedunine, epoxyazadiradione, 7-deacetoxy-7-oxogedunine, andirobin, gedunina. methyl angolensate, 6α-acetoxigedunina. 6β-acetoxygedunine, 6α, 11β-diacetoxigedunina, 6β, 11β-diacetoxigedunina, 11βacetoxigedunina, 1,2-dihydro-3β-hydroxy-7-deacetoxy-7-oxogedunine, 17βhydroxyazadiradione, xylocensin k, deacetylgedunina and 7- deacetylgedunin (Ambrozin et al., 2006; Costa-Silva et al., 2007; Costa-Silva et al., 2008; Ferrari et al., 2011; Miranda Júnior et al., 2012).

The unsaponifiable fraction of andiroba oil (2% to 5%) presents as major compounds tetranortriterpenoids (or limonoids), of which 6α-acetoxygedunine (7%), 7-deacetoxy-7-oxo-gedunine (7 %), andirobin (4%), gedunin (3%) and methyl angolensate (6%) (Ferrari et al., 2011).

Table 4. Andiroba (*Carapa guianensis* Aubl.) oil fatty acids composition

Unsaponifiable fraction	
glyceride 1,3-di-benzene carbonamine-2-octadecylic acid	1,2-dihydro-3β-hydroxy-7-deacetoxy-7-oxogedunine
2,6-dihydroxymethylbenzoate	6β, 11β-diacetotygedunine
3,4-dihydroxymethylbenzoate	11β-acetoxygedunine
naringenin	6α, 11β-diacetoxygedunine
tetratriacontanoic acid	17βhydroxyazadiradione
triacontanoic acid	xylocensin k
ursolic acid	deacetylgedunine
scopoletina	7- deacetylgedunin
2,3-dihydroxy-glyceride hexacosanoic acid	andirobin
6α-acetoxyepoxyazadiradione	gedunine
6α-hydroxygedunine	methyl angolensate
epoxiazadiradione	6α-acetoxygedunine
7-deacetoxy-7-oxogedunine	6β-acetoxygedunine

IV. Andiroba Applications

- **Plant parts**

The plant parts of the species *Carapa guianensis* Aubl., as well as their derivatives, have been used by traditional inhabitants of the Amazon rainforest for many years for different purposes, being used in isolation or associated with other plant / derivative drugs for the prevention and treatment of illnesses. The andirobeira bark is used as cicatrizant and vermifuge (Ferraz&Mendonça 2006).

Although the AO (extracted from seeds) of this species is the one with the highest number of citations regarding its popular use in the literature, the use of tea or decoction of the stem bark, leaves, flowers and flowers oil extracted from stands out, with the popular medicinal indication being similar to that attributed to oil extracted from the seed, as shown in (Table 5).

In the researched literature, reports were found that the caboclos, traditional inhabitants of the Amazon rainforest who live on the river bank, make a medicinal soap containing crude andiroba oil, wood ash and cocoa skin residues. This soap is especially recommended for the treatment of skin diseases. In addition, andiroba oil can be applied directly to the joints to relieve arthritis pain, and when mixed with hot water and human milk, it is used in drops for ear infections (Hammer & Johns, 1993; Nayak et al., 2010; Nayak et al., 2011).

Table 5. Applications of andiroba (*Carapa guianensis* Aubl.) on health healing

Used part	Popular medical indication
Bark	***Analgesic:*** relief of pain in cases of uterine cancer arthritis and rheumatism
	Anti-inflammatory: throat inflammation, contusions, skin inflammations and splenitis
	Antipyretic
	Healing: used in general wounds in insects bites
	Antiseptic
	Against infections: respiratory tract infections, skin infections, ear infections, bacterial infections and hepatitis
	Insect repellent and insecticide
	Anti-helminthic / antiparaditional: worms and scabies (canin)
	Antianemic
	Antidiarrheal
	Reduces the level of blood glucose (diabetes)
	Digestive stimulant
Leaf	***Analgesic:*** relief of pain in cases of rheumatism
	Skin problems
	Contusions
	Antipyretic
	Healing
	Pharyngitis
	Against intestinal worms
	Insect repellent
Seed	***Analgesic:*** relief from pain in cases of arthritis
	Anti-inflammatory: contusions
	Antipyretic
	Healing: used in cuts and bites of insects
	Emollient
	Against bacterial infections
	Insect repellent
	Vermifuge
Flower	***Analgesic***

	Bronchitis
	Antipyretic
	Against infections: respiratory tract infections and bacterial infections
	Anthelmintic: worms
	Antidiarrheal
	Antianemic
	Against tumors
Flower oil	***Healing:*** used in general wounds
	Prevention of skin diseases
	Insect repellent

Ministry of Health and ANVISA, 2015.

- **Andiroba oil**

In the Amazon region, this oil has an important commercial value. Used by the pharmaceutical and cosmetic industry, it has numerous health benefits. In the extraction process, there are two residues: the seed husk and the mass. Because it has insecticidal properties, the shells are burned to keep mosquitoes away. The residue of the pasta is used as food for cattle and in the homemade manufacture of andiroba soap (Mendonca &Ferraz, 2007).

Pharmaceuticals: In folk medicine, AO is widely used for cough and sore throat treatments, also for muscle bruises, skin lesions (Penido et al, 2006; Nayak et al., 2011). Used to relieve bruises, edema and healing due to its excellent penetration into the skin (Penido et al., 2006). Some studies suggest that other pharmacological activities, such as antitumor, insecticide and microbial, are also explored by the industry. As a repellent, to remove mosquitoes, leftovers from oil extraction, andiroba bagasse balls are burned or can also be applied in a mixture with annatto (*Bixaorellana*) to form a paste that protects the body against mosquito bites. The andiroba candle is used as an effective repellent for the Aedes aegypti mosquito, a vector of yellow fever and dengue. When burned, it exhales an active agent that inhibits mosquito hunger and, consequently, reduces its need to injure people. Research has shown a 100% efficiency in repelling mosquitoes, a result never found in any other product on the market for mosquito control. In addition to this characteristic, the candle is completely non-toxic, does not produce smoke and does not contain perfume. The external use of andiroba oil is indicated as a repellent, against parasites and itching in general, as wound healing and to remove spongy flesh from the eyes. Due to its good penetration into the skin, it is often used in massages to relieve swelling, dislocations, arthritis and rheumatism, also acting as a skin soothing and lightening of superficial spots. The internal use is recommended mainly to combat flu, fever, asthma, sore throat and even to decrease the level of glucose in the blood (diabetes). A mixture of AO and salt is widely used to prevent ticks in cattle (Mendonca &Ferraz, 2007).

Cosmetics: widely used in the manufacture of shampoos, as they strengthen and beautify hair and soaps to combat pimples and acne. These pharmacological properties are attributed to the presence of tetranortriterpenoids known as limonoids (Penido 2006). The Amazonian oil of andiroba is successfully applied in massage and is usually used for many diseases and skin conditions, including psoriasis. Sun protection creams with andiroba have excellent emollient properties and, due to their high concentration of unsaponifiable substances, they add the ability to repel insects to the sunscreen. Strengthens and beautifies hair and in the form of soap is a miracle cure in the fight against acne and pimples. This oil combined with another oil called copaíba, forms a natural ingredient extremely effective in controlling dandruff, besides providing shine to the hair. It also has anti-inflammatory property that reduces itching and treats the scalp.

Generally speaking, it is an oil with insect repellent properties and used to treat diseases such as arthritis, muscle strains, skin tissue disorders, rheumatism, malaria, kidney infection, hepatitis, cough, flu, pneumonia, bronchitis, severe ulcers, mycosis, protozoa and snake, scorpion and bee stings (Ferraz, 2003; Lima, 2010). Much sought after by the cosmetic and pharmaceutical industries due to its antiseptic, anti-inflammatory, curative and emollient properties (Revilla, 2001; Lorenzi, 2002; Ferraz& Camargo, 2003; Ferraz, 2003; Lima, 2010).

Table 5. Applications of andiroba (*Carapa guianensis* Aubl.) oil on health healing

Seed oil	***Analgesic:*** pain relief in uterine cancer, rheumatism, arthritis and torticollis
	Anti-inflammatory: throat inflammation, contusions and skin inflammation including psoriasis
	Antithermic
	Healing: used in general wounds, insect bites and ulcers
	Bactericide and fungicide
	Against infections: respiratory tract infections, skin infections, ear infections and bacterial infections
	Insect repellent and insecticide
	Anti-helminthic / antiparasitic: lice and tick
	Antidiarrheal

	Reduces the level of blood glucose (diabetes)

Ministry of Health and ANVISA, 2015.

V. Andiroba oil effect on living microorganisms

The effects of AO regarding living organism's control / inactivation specially against microorganisms and others (insects / parasites / protozoa) are shown in Tables 6 and 7, respectively.

- **Against microorganisms**

The living organisms regarding andiroba oil effect reported in the literature are mainly for bacteria, fungi and, in less, extent for yeast (Table 6).

BACTERIA

(a)*Xanthomonasaxonopodis* **-** Pires et al. (2015) conducted a study to verify the ability of AO to inhibit the bacterium *Xanthomonas axonopodispv. Passionflower*. Authors used pure AO in three concentrations (1, 2 and 3% for the bacteria). AO had a significant effect on the inhibition of bacterial growth at all concentrations used, being the higher concentration more efficient on inhibiting bacterial growth than the Control.

(b) *Klebsiella pneumoniae***-** Two studies reported in the literature the AO effect on *Klebsiella pneumoniae*. Meccia et al. (2013) applied oil extracted from andiroba leaf. The antimicrobial activity of the oil was tested using the diffusion method described by Velasco et al. (...). Filter paper discs impregnated with 10 µL of oil were placed on the agar surface. Paper discs impregnated with antimicrobial solutions were added. Inhibition halos were measured. To perform MIC determination, oil solutions ranging from 10 to 450 µg / mL were prepared using DMSO (dimethylsulfoxide) as solvent. The antimicrobial activity of the oil was determined using the disk diffusion assay. No antimicrobial activity was found for this bacterium. Already Silva and Almeida (2014) used the modified Kirby-Bauer method (Charles, 2009), using the disk diffusion test with *Klebsiella pneumoniae* strains and standardized antibiotics, andiroba peel ethanolic crude extract was used in concentrations 25, 50 and 100 mg/mL. Even its highest concentration showed low antimicrobial activity against *K. pneumoniae* strains.

(c) *Staphylococcus aureus* **-** As for the *Klebsiella pneumoniae*, two studies were found in the literature for *S. aureus*. The methodologies used were the same as those performed in (b), varying only the results. Meccia et al. (2013) observed activity against *S. aureus* only for oil at a minimum inhibitory concentration of 400 µg / mL. Already Silva and Almeida (2014) found no antimicrobial activity against the strain of this strain.

(d) *Escherichia coli* -As for the *Klebsiella pneumoniae*, two studies were found in the literature. The methodologies used were the same as those performed in (b), varying only the results. Meccia et al. (2013) observed activity against *E. coli* only for oil at a minimum inhibitory concentration of 400 µg / mL. Already Silva and Almeida (2014) found no antimicrobial activity against the strain of this strain.

(e) *Enterococcus faecalis, Salmonella typhi* **-** The methodology used was the same performed by Meccia et al. (2013) in (b), varying only the result. No antimicrobial activity was found for these bacteria.

YEAST

(a) *Candida albicans* and *Candida krusei*- Meccia et al. (2013) utilized oil extracted from andiroba leaf. The antimicrobial activity of the oil was tested using the diffusion method described by Velasco et al. (...). Filter paper discs impregnated with 10 µL of oil were placed on the agar surface. Paper discs impregnated with antimicrobial solutions were added. Inhibition halos were measured. To perform MIC determination, oil solutions ranging from 10 to 450 µg / mL were prepared using DMSO (dimethylsulfoxide) as solvent. The antimicrobial activity of the oil was determined using the disk diffusion assay. No antimicrobial activity was found for these yeasts.

(b) *Pseudomonas aeruginosa* - The methodology used was the same performed by Meccia et al. (2013) in (a), varying only the result. No antimicrobial activity was found for *P. aeruginosa* bacteria.

FUNGI

(a) *Colletotrichum gloeosporioides* - Two studies on the effect of AO on fungus (*C. gloeosporioides*) were found in the literature. Sousa et al. (2012) performed two tests, the first was an *in vitro* test to inhibit *C. gloeosporioides* growth and the second was the anthracnose. Control in postharvest pepper fruits with AO. In the first assay, the following oil concentrations 0.2 were added to the PDA culture medium; 0.4; 0.6; 0.8 and 1.0%. The Control consisted of a disc of the fungus grown in BDA medium without the oil. To evaluate the different concentrations of the oil in the mycelial growth of *C. gloeosporioides*, a culture medium disc (5 mm in diameter) was transferred to each Petri dish center. The evaluation of mycelial growth consisted of daily measurement of colony diameter. To Control anthracnose in postharvest pepper fruits, red pepper fruits were immersed for 5 min in a oil solution prepared in the highest concentration, used in the *in vitro* experiment, and

added to these Tween 20 (0.02% v / v). The inoculum consisted of 5mm diameter mycelium discs taken from colonies. Inoculation was performed using a wound method and depositing the inoculum on the fruit surface. The fruits were then placed in plastic trays, lined with filter paper and kept in a humid chamber at room temperature. For the analysis of lesion development, four measurements were made with a 48-hour interval, measuring the size of the lesion. AO was able to inhibit fungal growth as its concentration was increased, differing from the control from 1.0%. This fact suggests that increased oil concentration may have an inhibitory effect on fungal growth. The results observed for postharvest Control, using 1% concentration, showed oil efficiency on inhibiting the development of anthracnose lesion. Machado et al. (2013) conducted a study to verify the ability of andiroba oil for fungus inhibition. In order to study the effect of andiroba oil on the fungus, two different tests were foreseen. In the first, the oil was previously tested to pre-select for the next step. For this purpose, 9 cm diameter petri dishes were used, and about 15 mL of BDA medium containing 200 µL of the oil (adapted from OLIVEIRA et al, 2008) were added, in addition to the control treatment. After BDA solidification, a 1 cm diameter disc from the 7 day-old*C. gloeosporioides* culture edge was traced to the center of each plate. The evaluation of mycelial growth was verified daily by measurements. The oil was not efficient in this strain, therefore it did not pass to the second test.

(b) *Sclerotiumrolfsii*– Souza et al. (2019) conducted an experiment using andiroba and copaíba oil, which was carried out in a completely randomized design, in a 7 x 5 factorial design, the first factor being the two individual oils and five different combinations. And the second concentration 25, 50, 75 and 100 µL, for the pathogen *S. rolfsii*, and a control. Oil concentrations were diluted in (BDA), poured into Petri dishes. 0.5 cm diameter mycelium discs were transferred to the plates. The oils of andiroba and copaiba had significant control potential for the fungus *S. rolfsii*.

(c) *Postiaplacenta,Trametes versicolor* -Sousa et al. (2018) performed a toxicity assay on culture medium with brown and white rot fungi. For this assay, the method described by Medeiros et al. (2016). This method consists of placing the oil in a 0.6 cm diameter well, drilled in the center of the Petri dish, containing culture medium, for the development of the fungus. To this end, 20 mL of medium was added to each plate prepared by dissolving 15 g of agar and 20 g of maltose in 1 L of distilled water according to the methodology described in the American Society for Testing and Materials - ASTM D - 1413 (2018) 0.5% of the oil was added to each plate. The oil was incorporated pure or I_2 enriched in the proportions of 1, 3 and 5% by volume of oil. The 1 x 1 cm inocula were arranged at two opposite ends of the Petri dish. For the fungus Trametes versicolor, the greatest inhibition was andiroba oil with 1% I_2. For *Postia placenta*, the greatest inhibition was andiroba oil with 5% I_2.

Table 6. Characteristics of andiroba (*Carapa guianensis* Aubl.) oil applications against microorganisms reported in the literature.

Microorganism Group/Scientific name	**Andiroba oil application conditions**			
Bacteria	**Substrate**	**Concentration**	**Effect (inhibition)**	**References**
*Xanthomonas axonopodis**	Passion fruit root	1, 2, 3%	High	Pires et al., 2015
Klebsiella pneumoniae	PDA	10 - 450 µg/mL 25, 50, 100 mg/mL	No Low	Meccia et al., 2013 Silva & Almeida, 2014
Staphylococcus aureus	Biofilm	10 - 450 µg/mL 25, 50, 100 mg/mL	High No	Meccia et al., 2013 Silva & Almeida, 2014
Pseudomonas aeruginosa	Biofilm	10 - 450 µg/mL	No	Meccia et al., 2013
Escherichia coli	PDA	10 a 450 µg/mL 25, 50, 100 mg/mL	High No	Meccia et al., 2013 Silva & Almeida, 2014
Enterococcus faecalis	PDA	10 - 450 µg/mL	No	Meccia et al., 2013
Salmonella typhi	PDA	10 - 450 µg/mL	No	
Yeast				
Candida albicans	PDA	10 a 450 µg/mL	No	Meccia et al., 2013
Candida krusei	PDA	10 a 450 µg/mL	No	
Pseudomonas aeruginosa	PDA	10 - 450 µg/mL	No	
Fungi				
Colletotrichum gloeosporioide	Chili pepper PDA	0.2, 0.4, 0.6, 0.8, 1.0% 200 µL	High Inhibition of the development of injurie	Sousa et al., 2012 Machado et al., 2013
Sclerotium rolfsii	Tomato	25, 50, 75, 100 µL	High	Souza et al., 2019
Postia placenta	PDA	0.5, 0.5+1% I* 0.5+3% I 0.5+5% I	High	Sousa et al., 2018
Trametes versicolor	PDA	0.5 %, 0.5% + 1% I, 0.5% + 3% I, 0.5% + 5% I	High	Sousa et al., 2018

**pv. Passiflorae*iodine

- **Against insects,parasites and protozoa**

For the living organisms regarding AO effect reported in the literature, they are mainly for insects and parasites (and in less, extent protozoa) (Table 6).

INSECT

(a)*Sitophilus zeamais* Motschulsky – Coitinho et al. (2006) used two methodologies to perform the tests. the first was the *no choicetest*, where the oil was tested at a dose of 50µL / 20g of corn kernels. The grains were placed inside plastic containers and impregnated with each oil, with the aid of an automatic pipettor and stirred containers. Each 20g portion of grains was placed in a plastic container, with a perforated lid, allowing gas exchange with the outside infested with eight adults from *S. zeamais* aged zero to 15 days old. After 5 days of confinement, the live and dead insects were counted, and then discarded. The andiroba oil caused 90% mortality. In the *no choicetest*, AO is effective in terms of mortality and in reducing the emergence of adults of *S. zeamais* in corn kernels.

The second methodology was the *free choicetest*, where the oil was tested in arenas consisting of two plastic containers, symmetrically connected to a central box by two plastic tubes. In one of the boxes, 20 g of untreated corn grains were placed and in the other the same amount of grains treated with each oil. In the central box, 16 adults from *S. zeamais* aged zero to 15 days old were released. each experiment was carried out two treatments (oil and control) and 10 repetitions. After 24 h, the insects contained in each container were counted, to assess repellency and replaced in the arenas, where they remained for another 4 days. AO showed 68.6% repellency. in *free choicetests*, the oil is effective in reducing the emergence of adults in *S. zeamais*.

(b) *AnastrephafraterculusWiedemann*–Rosa`s et al. (2013) treatments consisted of andiroba oil in concentrations of 0.5, 1 and 2%, in association with 5% hydrolyzed protein. 5% hydrolyzed protein was the control treatment. The attractive solutions were placed in the yellow traps at a dose of 200 mL per trap. The traps were placed on the plants. The captured insects were separated from the attractive solution through a fine mesh plastic sieve and then washed in pure water and placed in 80 mL pots containing 70% alcohol, where the species were screened, counted, sexed and identified. The different doses of AO mixed with hydrolyzed protein significantly reduced the capture potential of *A. fraterculus.* The treatments containing a mixture with 0.5, 1.0, and 2.0% of AO captured 32.8, 9.1 and 6.8% of the total of flies collected, respectively.

(c) *Pseudohypocerakerteszi–* Freire et al. (2013) collected adult individuals of forids present in hives of *M. compressipesmanaosensis* naturally infested. the insects were kept in a wooden box lined with white sulfite paper and covered with PVC plastic film with small enough holes to allow ventilation. The box was kept at room temperature, where they were monitored until the insects died. The experiments consisted of monitoring the posture of the female phorids in plastic pots covered with beeswax. Six boxes (repetitions) were used. In each box, three substrates were offered: a) pot containing pollen (diluted in water 3:1), b) pot containing honey and c) pot containing pollen mixed with andiroba oil (60 mL). It was observed that the females of phorids performed laying on all types of substrates, indicating that the pollen substrate was preferably used for oviposition. females did not use the pollen pot mixed with andiroba for laying (inhibition of up to 100% of posture). From these results, andiroba oil was tested in 25 colonies of *M. compressipesmanaosensis* bees that were naturally infested with forids. With the help of absorbent paper, a thin layer of oils was passed on the inner walls of the trash can and the lid of these hives as well as around the entrance orifice. After 3 days, the presence of adult forids and larvae indicating the oil repellent action. No changes were observed in the development of bees from the colonies treated in this experiment.

(d)*Chrysomyamegacephala, Haematobiairritans*– Klauck et al. (2014) performed the *in vitro* repellency tests using a device with different compartments. In compartments 1 and 2, cotton wool soaked in 2 mL of oil or citronella was used (positive repellent Control); in compartments 3 and 4 there was cotton soaked in distilled water and triton (2 mL). There were interconnections between compartments with transparent tubes of 1.8 cm in diameter, which allowed the free movement of the fly. The flies selected for the test (90 samples each) were separated into 18 groups of 10 insects each. Later flies were exposed to andiroba, and 5.0% tea tree oils and citronella oil (positive repellent control). The test started when the flies were placed in compartment 1, together with the cotton wool that contained the test solution. Then, compartments 2, 3 and 4 were opened to allow free movement of the fly. To assess the repellent effect, after treatment, all flies were counted in each compartment at predetermined intervals. The effect of AO was 75% for *Chrysomyamegacephala*. An important result to be reported was the death of the flies that remained in the compartments with andiroba oil. AO also had a repellent effect for *Haematobiairritans*.

(f) *Tenebrio molitor* – Lima et al. (2015) used larvae of the 4th instar of *Tenebrio molitor* as a model insect. The formulations based on AO and alcoholic extract of the tegument consisted of 50 ml of the product

and 20 ml of liquid soap. For each plant extract, bioassays were performed at concentrations of 1 and 10%, considering the lowest and highest limit dose for biological response for each formulation, in addition to a control treatment with distilled water. The exposure to treatments was through topical application on the insect. After applying the treatments, the insects were kept in air-conditioned chambers. The mortality of the insects studied was evaluated over 5 days after their exposure to the insecticides tested. Formulation based on AO, at a concentration of 1%, presented increasing mortality rates of 67.5% (1st day), 77.5% (2nd day), 82.5% (3rd day), 85% (4th day) and 90% (5th day). At the 10% concentration, the mortality rates were 97.5% (1st day) and 100% on the other days. Treatment with a formulation based on AO showed higher mortality rates at concentrations of 1% and 10%, compared to treatment based on alcoholic extract of the integument. In addition, the action time in the case of oil formulation was shorter for concentrations of 1% and 10%, with mortality rates of 67.5% and 97.5% on the first day of evaluation.

PARASITE

(a) *Aedes aegypti* – Two studies on the effect of andiroba oil on the parasites *Aedes aegypti* were found in the literature. Silva et al. (2006) evaluated the larvicidal effect of AO, against two strains of *Aedes aegypti*. After 8 h after exposure to oil. The values of lethal concentrations (LC) 90 and LC95 for the larvae of the GCZ strain (resistant to temefos) were 80 and 86 ppm (1st instar), 98 and 106 (2nd instar), 166 and 182 (3rd instars) and 192 and 202 ppm (4 instars), respectively. The LC_{90} and LC_{95} values for Rockefeller line larvae were 164 and 182 ppm (1st instar), 212 and 224 (2nd instar), 210 and 226 (3rd instar) and 450 and 490 ppm (4 instar), respectively. To evaluate the sublethal effect of C. guianensis oil in the development of A. aegypti concentrations corresponding to CL50, CL_{20}, and CL_{10} were used. For AO, the concentrations were LC_{50}, 140 mg/L; CL_{20}, 60 mg/L; and CL_{10}, 40 mg/L. Three replicates were prepared, each containing 500 mL of solution in plastic containers with a capacity of 1,000 ml. For larvae feeding, puppy food was crushed (0.36 g) in each replica. Three hundred larvae of late third and early fourth instar were placed in each replica, totalizing 900larvae per bioassay. Larval behavior, such as feeding, phase changes, alteration in mobility, weakness, and mortality, as well as emergence of adults were daily checked. Every 96 h, food was added to the treated and Control group. To evaluate the sublethal effect of AO on the development of *A. aegypti* concentrations corresponding to CL_{50}, CL_{20} and CL_{10}, Prophiro et al. (2012) used concentrations of LC50, 140 mg / L; CL20, 60 mg / L; and CL10, 40 mg / L of andiroba oil. Three replicates were prepared, each containing 500 mL of solution in plastic containers with a capacity of 1,000 mL. In each replica, three hundred larvae were placed at the end of the third and beginning of the fourth initial stage, totaling 900 larvae per bioassay. The lethal effect started 1 h after exposure, but between the first 2 and 3 h, larvae mortality was more expressive. When concentrations of 1,400 mg/L of C. guianensis were used, all larvae were active with normal movements of zigzag in the first 5 min of exposure. After this time, behaviors such as slow movements, tremors, convulsions followed by paralysis and death were observed in most larvae exposed to the solutions. The larvicidal effect of solutions containing AO remained with total efficiency (100% mortality) until the12th day. Then it decreased from 97 to 92% on the 13th and 14th days, respectively. No more larval mortality was observed after the 32nd day. When using LC50, 140 mg/L of C. guianensis, 100% of mortality in 72 h was observed. In the same way, CL_{20},60 mg/L, 100% mortality in 96 h was observed. It was observed that in both concentrations (LC50and CL20), mortality continued after the larval molt. Pupae and adult emergence were not observed in this treatment. CL_{10},40 mg/L induced 99.7% mortality after 1 week of treatment. With this concentration, from 900 exposed larvae, only three emerged to become an adult after 10 days, apparently without alterations. In the control groups, no mortality within 24 h of exposure was observed.

(b) *Rhipicephalus (Boophilus) microplus, Rhipicephalus sanguineus, Anocentornitens* – Farias et al. (2012) Andiroba oil was tested on engorged females of *Rhipicephalus (Boophilus) microplus*, *Rhipicephalus sanguineus and Anocentornitens.*Engorged females were cleaned with absorbent paper and separated based on aspects of normal appearance and motility, intact body and maximum engorgement (Leite et al., 1995), distributed in a Petri dish in a group of ten, weighed on an analytical scale and submitted the immersion test recommended by Drummond et al. (1971, 1973). Five dilutions of andiroba seed oil (20, 10, 5, 2.5 and 1.25%) were used using distilled water and tween 80 as dispersant, with three repetitions per treatment, forming, still, a control group, a negative control only with distilled water, and another positive control with the chemical acaricide based on cypermethrin. To evaluate the effectiveness of andiroba oil on non-fed larvae, the "sandwich" technique recommended by Shaw (1966) adapted by Milk (1988) was used. Ten days after the start of laying, the eggs were separated into one-gram batches and packed in adapted 20ml plastic syringes, sealed with cotton wool and incubated in a climate-controlled chamber for B.O.D. hatching of the larvae destined for the test. Six dilutions of andiroba seed oil (20, 10, 5, 2.5, 1.25 and 0.75%) were prepared using distilled water and tween 80 as dispersant, and a control group with distilled water and another with tween 80 and distilled water.Approximately 100 larvae from 14 to 21 days of age were placed between two pieces of filter paper impregnated with dilutions of andiroba seed oil. Then this set was placed in a filter paper envelope and sealed

with adhesive tape and kept in a climate-controlled chamber for B.O.D. until reading its feasibility. The registration of live and dead larvae was performed 24h after the test. In the tests performed on the oviposition of engorged females, an IC50 of 4.332 was obtained; 4,850 and 4,903 for *R. (B.) microplus*, *A. nitens* and *R. sanguineus* respectively. AO seed oil, at a dilution of 1.25%, inhibited oviposition by 10% for *R. (B.) microplus*, 6.67% for *A. nitens* and 10% for *R. sanguineus*, reaching a tick-effectiveness of 27.82%, 20.01% and 18.01%, respectively, with better efficacy demonstrated in concentrations greater than 5%. The mortality of engorged females ranged from 10 to 100% for *R. (B.) microplus* and *Rhipicephalus sanguineus* and from 6.67 to 100% for *A. nitens*.

(c) *Trichostrongylus sp., Haemonchus sp., Oesophagostomum sp., Strongyloides sp.* – Moraes et al. (2010) applied hexane extract from the seed of *Carapa guianensis*. Fecal samples from goats and sheep were used, which were collected directly from the rectal ampoule of animals naturally infected by helminths, where they were processed to determine the number of eggs per gram of feces according to the technique of Gordon & Whitlock (1939), interpreting them the degree of infection according to Ueno & Gonçalves (1998). From each animal species, fecal samples were selected, forming a homogenate for the cultivation of larvae, according to the technique described by Robert & O'Sullivan (1950). Each cultivation was subjected to 5 concentrations of AO (100, 50, 30, 25 and 10%), using tween 80 as a dispersant. The cultivation of gastrointestinal nematode larvae of the caprine species in the Control groups (C1 and C2) revealed infectious larvae of the genus *Haemonchus*, *Oesophagostomum* and *Trichostrongylus*, with predominance of the genus *Haemonchus*.

Analyzing the reduction percentage in the goat species, considering the negative Control C1, a highly effective reduction was demonstrated for the treatments of 100, 50 and 30% and positive Control for the *Haemonchus* and *Oesophagostomum* genera, and in the total number of larvae and moderately effective for the genus *Trichostrongylus* in all treatments. The ovicidal activity against gastrointestinal nematodes of goats and sheep in vitro, demonstrated by the AO shows the anthelmintic activity of this herbal medicine and the possibility as an alternative for the control of gastrointestinal nematodes of goats and sheep.

PROTOZOA

(a) Trypanosoma evansi – Baldissera et al. (2013) used pure oil in the concentration of 0.5, 1.0 and 2.0% against *T. evansi*. Subsequently, the same tests were carried out, using nanoemulsion oils in concentrations of 0.5 and 1.0%. the number of parasites was quantified at 1, 3 and 6 hours after the start of the study. A dose-dependent reduction in the number of parasites was observed in the forms of the two oils tested after 1 h. The parasite concentration was significantly reduced at low concentrations after 3 h, and at 6 h, no live parasites were observed for the tested oils. AO (in conventional and nanoemulsion forms) has high activity against *T. evansi* in vitro, suggesting that this oil can be applied as an alternative treatment for this disease.

***(b) Plasmodiumfalciparum* –** Junior et al. (2012) performed the antiplasmodial activity of AO and its fraction rich in limonoids in 96-well tissue culture plates, as previously described (Rieckmann, 1980; Carvalho et al., 1991; Mitaine-Offer et al., 2002). Twofold serial dilutions of limonoid-rich fraction dissolved in sterile methanol, and AO dissolved in DMSO solution, were placed in micro titer plates and diluted with the culture medium. A suspension of parasitized erythrocytes (0.5–1% parasitaemia, 2.5% hematocrit) containing mainly trophozoites was added to the wells to reach a final volume of 100 mL. For AO were used the concentrations 820, 82, 8.2, 0.82 and 0.082 mg/mL, while for limonoid-rich fraction the concentrations were 100, 50, 25, 12.5, 6.25 and 3.125 mg/mL. Andiroba oil and its limonoid-rich fraction inhibited the growth of W2 clone in 100%, between 24 and 72 h, at concentrations of 8.2 and 3.1 mg/mL, respectively. For the limonoid-rich fraction the inhibition of Dd2 clone was 56% (IC50 2.8 mg/mL) at 24 h, 64% (IC50 2.4 mg/mL) at 48 h and 82% (IC50 0.4 mg/mL) after 72 h. For Dd2 clone, in both experiments with AO and limonoid-rich fraction, the final response at 72 h (IC50 8.4 mg/mL and IC50 0.4 mg/mL) was more positive than the initial response of 24 h (IC50 4 82 mg/mL and IC50 2.8 mg/mL). Pereira et al. (2014) used the following compounds isolated from AO: 6α-acetoxyepoxyazadiradione (1), andirobin (2), 6α-acetoxygedunin (3) and 7-deacetoxy-7-oxogedunin (4) (all isolated from residual pressed seed material using extraction and chromatography techniques). They also studied: 6α-hydroxy-deacetylgedunin (5) (prepared from 3) were evaluated using the micro test on the multi-drug-resistant *Plasmodium falciparum* K1 strain. The efficacy of limonoids 3 and 4 was then evaluated orally and subcutaneously in BALB/c mice infected with chloroquine-sensitive Plasmodium berghei NK65 strain in the 4-day suppressive test. In vitro, limonoids 1-5 exhibited median inhibition concentrations (IC50) of 20.7-5.0 μM, respectively. 6α-acetoxygedunin is an abundant natural product present in AO residual seed materials that exhibits significant in vivo anti-malarial properties.

Table 7. Characteristics of andiroba (*Carapa guianensis* Aubl.) oil applications against insects, parasites and protozoa reported in the literature

Living organism Group / Scientific name	**Andiroba oil application conditions**	**References**

Insect	Common name	Concentration	Effect	
Sitophilus zeamais Motschulsky	Corn weevil	50 µL/ 20 g corn	Insecticide	Coitinho et al., 2006
Anastrephafraterculus Wiedemann	Fruit fly	0.5, 1, 2%	Repellency	Rosa et al., 2013
Pseudohypocerakerteszi	Hive	60mL	Repellency	Freire et al., 2006
Chrysomyamegacephala	Oriental latrine fly	5%	Repellency	Klauck et al., 2014
Haematobiairritans	Horn fly	5%	Repellency	Klauck et al., 2014
Tenebrio molitor	Flour larva	1, 10%	Insecticide	Lima et al., 2015
Parasite				
Aedes aegypti	Dengue mosquito	- 40, 60, 140 mg / L	Acaricidal / larvicidal	Silva et al., 2006; Prophiro et al., 2012
Rhipicephalus (Boophilus) microplus	Tick (ox)	1.25, 2.5, 5, 10, 20%	Acaricidal	Farias, et al., 2012
Rhipicephalus sanguineus	Tick (dogs & horses)			
Anocentornitens	Tick (dogs & horses)			
Trichostrongylus sp.	Goats & sheep	10, 25, 30, 50, 100%	Anthelmintic	Moraes et al., 2010
Haemonchus sp.	Goats & sheep			
Oesophagostomum sp.	Goats & sheep			
Strongyloides sp.	Goats	10, 25, 30, 50, 100%	Anthelmintic	Moraes et al., 2010
Protozoa				
Trypanosoma evansi	Ill of chairs	0.5, 1, 2%	Anti-parasitic	Baldissera, 2013
Plasmodium falciparum	Malaria	820, 82, 8.2, 0.82, 0.082 mg / mL -	Antiplasmodial Anti-malarial	Junior et al., 2012; Pereira et al., 2014

VI. Conclusion

This oil affects some microorganisms, such as bacteria, fungi and yeasts, as well as insects, parasites and protozoa, serving as a light and promising method of decontamination.

AO has much of its use as a natural insect repellent. And for its insecticidal action, it is widely used in the production of aromatizing candles, in order to ward off insects and make soap, helping in the treatment of itches and stings, due to its curative property.

It can also be applied to furniture and wood, preserving and protecting them from termites, in addition to increasing durability.

In the cosmetics industry, it is widely used due to its emollient property, which provides hydration and nutrition to the skin and hair.

It has curative and anti-inflammatory action, which is improved when massaged, relaxing the muscles and relieving muscle pain and inflammation. On the skin, it helps to fight cellulite and to disappear blemishes and scars, besides providing smoothness.

Due to this anti-inflammatory property, it also affects bruises, bumps, rheumatism and skin diseases. It assists in the regeneration of inflamed tissue and softens the skin when rubbed over the injured area.

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