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► **To cite this version:**

M.C. C Lisboa, F.M.S. M S Wiltshire, R L Souza, A.T. T Fricks, C. Dariva, et al.. Oleochemistry potential from Brazil northeastern exotic plants. *Biochimie*, In press, 10.1016/j.biochi.2020.09.002 . hal-02946034

HAL Id: hal-02946034

<https://hal.science/hal-02946034>

Submitted on 22 Sep 2020

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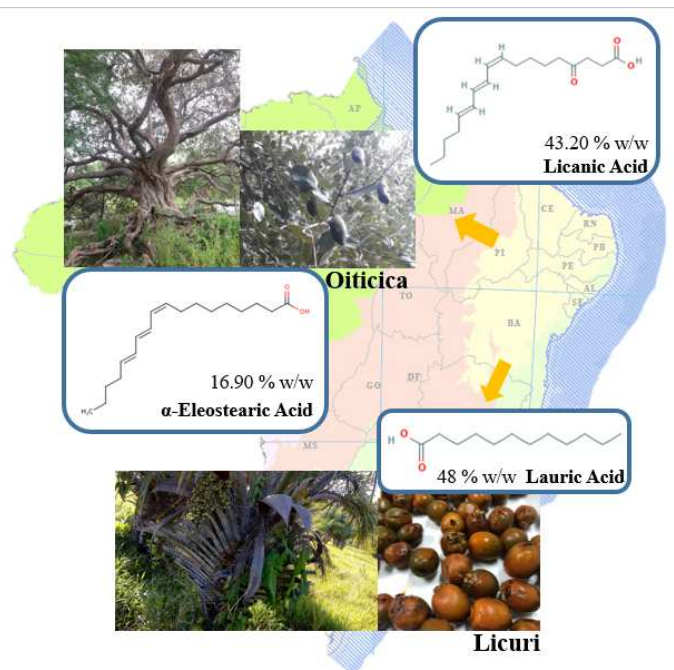
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4 **OLEOCHEMISTRY POTENTIAL FROM BRAZIL NORTHEASTERN EXOTIC**
5 **PLANTS**

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17 **Abstract**

18

19 Caatinga is a Brazilian semi-arid ecosystem that stands out for presenting unique
20 environmental characteristics with a dry, spiny and deciduous shrub/forest vegetation
21 with several species that can be renewable oil sources with potential applicability in
22 oleochemical and nutrition. Caatinga oilseeds have a high content of unsaturated fatty
23 acids, phytosterols and sterols, and this composition is related to its nutritional potential.
24 The present review summarizes the knowledge on the oil contents and fatty acid profiles
25 of seeds from six representatives caatinga species. It was observed that plants species
26 like Caju (*Anacardium occidentale* L.), Favela (*Cnidoscolus quercifolius* Pohl), Licuri
27 (*Syagrus coronata* (Mart.) Becc.), Pinhão-bravo (*Jatropha mollissima* Pohl Baill),
28 Pequi (*Caryocar brasiliense* Camb) and Oiticica (*Licania rígida* Benth) contains
29 approximately 33.1, 33.5, 49.2, 18.3, 70.16 and 57.0 % w/w of oil, respectively, on a
30 dry weight basis. Their fatty acid profiles are mostly saturated for Licuri oil, with a high
31 content of lauric acid (up to 40%) and unsaturated for Favela, Pinhão-bravo, Cashew
32 nut, Pequi and Oiticica oils. Oiticica oil shows a high concentration of unusual
33 conjugated polyunsaturated fatty acids, like α -Eleostearic and Licanic acid with 16.90
34 and 43.20 % w/w, respectively.

35

36 **Keywords:** plant, oil, food, Brazil, Caatinga.

37 **1. Introduction**

38 The number of plants for food consumption is estimated to hundred species,
39 among which rice, wheat and maize account for 60% of the total caloric intake [1]. One
40 alternative to recover old eating habits for health promotion is using different plant
41 species as food [2]. This stimulates an interest in accessing plant foods in biodiversity
42 centers, in order to find different and attractive tastes, as well as high levels of bioactive
43 substances capable of preventing many diseases [3]. Brazil can contribute enormously
44 in this field because the country has the most diverse flora of the world, with 33,200
45 different species approximately, what corresponds to 26.5% of the total known plant
46 species [4].

47 In Brazil there are different types of land and climates that results in a large
48 diversity of species distributed around six main biomes, namely the Amazon Forest,
49 Caatinga, Cerrado, Atlantic Forest, Pantanal and Pampa, as shown in Figure 1. [5; 6; 7].
50 Caatinga is a semi-arid ecosystem with an area of 969.589.4 km², being an exclusively
51 Brazilian biome that covers their northeast, composed by the states of Alagoas, Bahia,
52 Ceará, Maranhão, Paraíba, Pernambuco, Piauí, Rio Grande do Norte and Sergipe and
53 small portion southeastern area in the state of Minas Gerais north. The name has a Tupi-
54 Guarani origin and means white forest. This name appropriately characterizes the
55 physical aspect of the vegetation during the dry season, when the leaves fall and only
56 the bright white trunks of trees and shrubs remain on the dry landscape. It corresponds
57 to 10% of the Brazilian territory and 60% of the northeastern region [8]. Its vegetation
58 covers a continuous area of semi-arid climate, limited by areas of typically humid
59 climate. This area, dry and hot, is defined as the drought polygon. The species present in
60 the Caatinga have as characteristics marked adaptations to water scarcity, i.e deciduous,
61 annual herbaceous, succulent, the presence of aculeus and leaves transformed into
62 thorns are constant, shrub and small trees are predominant and the canopy cover is

63 irregular. Its worth mentioning that there is presence of endemic species and non-
64 endemic species. Non-endemic species occur in other areas of similar climate but are
65 not found in humid regions that limit the biome [9]

66 Caatinga have an annual average rainfall that ranges from 240 to 1500 mm,
67 restricted from January to March, with 2.000 mm of evaporation rate and high annual
68 temperatures (around 27 ° C). Due to the low rainfall, the environment shows a shallow
69 and stony soil with the presence of temporary rivers and streams. This periodic severe
70 drought makes life difficult for the human inhabitants and provide adaptive challenges
71 for the region's biota due to this unique environmental condition [8].

72 In this way, more than 510 genera and 5344 species of vascular plants have been
73 identified in the Caatinga, among which 18 genera and 318 species are endemic [10].
74 Therefore, the climate and soil of the northeast region are determining factors of their
75 typical vegetation [11]. Several plant species of the Caatinga are potentially useful as oil
76 seed sources. Thus, the objective of this mini-review is to summarize the properties of
77 oils and fatty acids that can be extracted from some representative species shown in
78 Figure 2, of the Brazilian caatinga and present potential applications in Oleochemistry.

79 Among the six species selected for this review, Favela (*Cnidoscolus quercifolius*
80 Pohl), Licuri (*Syagrus coronata* (Mart.) Becc.), Pinhão-Bravo (*Jatropha mollissima*
81 Pohl Baill) and Oiticica (*Licania rigida* Benth) are endemic and naturally occur in
82 Caatinga while Cashew (*Anacardium occidentale* L.) is a Brazillian native plant that
83 occurs naturally on the coast and in the semi-arid region, and Pequi (*Caryocar*
84 *brasiliense* Camb), naturally occurring in the Cerrado, was adapted to the northeast
85 region and in the transition regions of the Amazon rainforest and Caatinga.

86

87 **2. Cashew nut** (*Anacardium occidentale* L)

88 Commonly known as “Caju”, belongs to the Anacardiaceae family, native from
89 the Brazilian north and northeast regions. Cashew tree is adapted to various regions of
90 different climates and water availability, being popular in houses backyards. It’s a
91 perennial plant, with botanical characteristics as an aerial stem with low branching; the
92 leaves are simple, petiolate and without stipulation; the leaf is leathery, the leaves are
93 alternate and obtuse; the inflorescence is panicle, the flowers are pentamerous, and may
94 be complete (bisexual) and masculine (with stamens). The fruit is achene, the chestnut
95 is the real fruit, formed by the pericarp and the seed or almond, and the peduncle is the
96 pseudofruit [12; 13]

97 The dispersion of cashews was carried out by Brazil colonizers in the 16th
98 century and is currently found in various parts of the world like Vietnam, India, and
99 Nigeria. In the 1990s, EMBRAPA (*Empresa Brasileira de Pesquisa Agropecuária*, in
100 English: Brazilian Agricultural Research Corporation) started to offer small size cashew
101 clones, to facilitate the harvest, these crops came from asexual propagation by grafting
102 and had a high genetic quality. From these developments, it is now possible to increase
103 the cashew productivity and rentability in Brazil [12; 14]

104 Cashew is grown especially in small and medium-sized farms, in agricultural
105 associations and rural settlements [12]. The Northeast region of Brazil is largely
106 responsible for the national production of cashew nuts, with 98.8% of the total produced
107 in Brazil. In 2017, the annual production in the Northeast region was 132 thousand tons
108 of nuts, of which 81 thousand (60.8%) were produced in the state of Ceará [15].
109 Worldwide, the area occupied by cashew trees is equivalent to 3.39 million hectares,
110 constituting in the production of chestnuts, pseudofruit (peduncle) *in natura* and

111 derivatives such as juices, jelly and sweets [12; 14]. Cashew bark boiled in water can be
112 used to treat non-infectious diarrhea and as an antiseptic and healing agent [16]

113 The fruit and pseudofruit of this species are used in the food, cosmetics and
114 pharmaceuticals manufacturing. The oil from the nut has a high nutritional value, with a
115 high content of oleic acid and other bioactive compounds like tocopherols and sitosterol
116 [17 and 18]. The Soxhlet extraction yield of cashew nut oil using petroleum ether / ethyl
117 ether 1: 1 (v/v) is approximately 33.1 ± 0.6 % w/w, but this percentage may vary
118 according to the extraction methodology. The major acids present in cashew oil are
119 oleic acid, followed by linoleic acid and palmitic [17].

120

121 **3. Favela** (*Cnidoscolus quercifolius* Pohl or *Cnidoscolus phyllacanthus*)

122 Belonging to the Euphorbiaceae family, Favela it is well recognized for its high
123 drought tolerance. Its xerophilic character allows the plant to grow and reproduce, even
124 in prolonged periods of drought, helping to maintain the balance of the ecosystem by
125 mitigating environmental degradation [19]. Favela tree is an arboreal plant (reaches 4
126 meters in height) with abundant spines, with characteristic tuberous roots, also called
127 xylopodia, specialized in storing organic matter produced in the rainy season and used
128 during the drought. At the end of the rainy season, the leaves ripen and fall, this
129 characteristic represents greater resistance during droughts. The leaves are long, thick,
130 lanceolate, with the presence of stems in the limbus, the stinging spines can be constant
131 or not. There are also thorns at the leaf insertion sites. The flowers are dioecious, with
132 pentameric petals. The fruit is dry, dehiscent, capsule-shaped and has stinging hair on
133 the surface [20; 21]. The propagation of the favela occurs sexually from the propagation
134 of seeds. Although the plant is monoecious, there is a prevalence of cross-fertilization,
135 with the dehiscence of the fruit occurring between 56 and 57 days after fertilization and

136 the subsequent explosive opening of the fruit launching the seeds 30 m away from the
137 mother plant. The asexual propagation is complex, since the species has a difficult
138 rooting process, with no records of planting fields from seedlings [22]

139 The seeds are brown-gray, ovoid, rigid and smooth, similar to those of castor
140 bean (*Ricinus communis* L.), which belongs to the same family. Silva et al. (2014) [23]
141 reported in a study of 100 species from the Caatinga Euphorbiaceae family, showing
142 that favela is the species with the highest oil content (22.6–33.5% w/w). Favela oil is
143 edible, and its seed has no toxic proteins, so this oilseed plant represents a potential oil
144 source for human nutrition. However, handling and consumption must be done with
145 care due to the toxicity generated by hydrocyanic acid [21; 22] The distribution of fatty
146 acids showed that the favela oil is made up of fatty acids with 14–20 carbons.
147 Unsaturated fatty acids predominated (75.49%), with linoleic (C18:2n6) and oleic acids
148 (C18:1n9) representing 54.39 and 20.13% of total fatty acids, respectively.

149 Thus, Favela oil may be an alternative to similar edible oils such as sunflower oil
150 (*Heliantus annuus* L.) and soybean oil (*Glycine max* L.). According to Arriel et al.,
151 (2005) [24] Favela dry leaves and barks are usually eaten by cattle, sheep, goats and
152 donkeys, while the seeds are used for feeding chicken and pigs.

153 Besides that, Favela is a well know medicinal plant from Caatinga, being widely
154 used in folk medicine in the treatment of injuries, urinary tract infections and
155 inflammatory processes. Most recently Oliveira-Junior et al., 2018 [25] confirmed that
156 compounds extracted from Favela stem barks have a great antibacterial potential against
157 several bacterial strains tested (*E. faecalis*, *S. aureus*, *E. coli*, *K. pneumoniae* and *S.*
158 *marcescens*). Reports of favela use in folk medicine is part of the popular
159 pharmacopoeia. The species also has the presence of latex, widely used for medicinal
160 purposes. Favela is present in the semiarid regions of Caatinga, specifically in the states

161 of Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, southwestern
162 Piauí, some regions of Bahia and northern Minas Gerais [21]

163

164 **4. Licuri** (*Syagrus coronata* (Mart.) Becc.)

165 This highly drought-resistant palm tree from Arecaceae family, is an endemic
166 species in semi-arid regions of the Caatinga, covering the eastern and central areas from
167 Minas Gerais North to Pernambuco South. Licuri palm tree has a medium height
168 measuring between 8 to 11 m. Being also called big-headed coconut, it has a stipe stem
169 covered by old leaf sheaths. The plant is monoecious, the male flowers are long,
170 contains six stamens and a leathery aspect. The female flowers are smaller and have a
171 supernary ovary. The yellowish inflorescence can reach up to 1m in length.

172 Licuri fruit is classified as drupa for being a highly developed, divided into two
173 very specialized parts, with the fleshy mesocarp, often edible, attractive for dispersion,
174 and a hard endocarp, which protects the seed. This drupa fruit has a liquid endosperm
175 that, as it ripens, it turns into a fleshy (solid) endosperm that will originate the almond.
176 After ripening the fruits go from green to a light yellow-orange color [20; 26]. It can
177 bloom and bear fruit for several months of the year, however the months of March, June
178 and July are the more favorable for better fruit production. Licuri palm tree is one of the
179 most explored native species in northeastern Brazil. The extractivism of native species
180 is the main form of exploitation, considering that their propagation is sexual.

181 According to [26] the time necessary for Licuri palm tree to provide mature
182 fruits is between 6 to 8 years old. Each tree can produce four bunches per year. Licuri
183 bunches are 30 to 40 cm long, have an average of 1.357 small coconuts, each 2 to 3
184 centimeters long and approximately 1.5 cm in diameter. However, the production of

185 Licuri Fruits may vary according to the amount and distribution of rainfall, soil
186 conditions and the presence of other native plants.

187 Through appropriate management practices it is possible to improve and
188 maintain higher production averages. In conditions of adequate moisture, temperature
189 and light, germination can take between 3 and 4 months. Dormancy break treatment is
190 recommended to accelerate the germination process and optimize [27]

191 According to Crepaldi et al., 2001 [28], the oil is concentrated in the endosperm
192 of the seed fruit, having 49.2 % w/w_{dry} of lipids, against 4.5% w/w_{dry} of lipids in the
193 mesocarp. Licuri endosperm oil is an important food and feed resource for humans and
194 animals in semi-arid zones. It is widely exploited for frying, cooking and soap
195 production. The flavor of Licuri seeds and oil is reminiscent of that of coconut (*Cocos*
196 *nucifera*) reaching few shades of taste and aroma of the almonds, probably due the high
197 percentage of lauric acid in its composition (>40% of total fatty acids). Studies
198 conducted by Pereira et al., 2010 [29] demonstrated that Licuri endosperm oil
199 supplementation in goat milk led to higher acceptability scores for flavor and odor. In
200 addition, Santos et al., (2019) [30] demonstrated that Licuri oil has antibacterial
201 properties against *S. aureus*, thus having potential in antimicrobial product
202 development, but so far there is no record in the pharmacopoeia.

203

204 **5. Pinhão-Bravo (*Jatropha mollissima* Pohl Baill)**

205 Belongs to the Euphorbiaceae family, which comprises approximately 321
206 genera and 8000 species. The name of the *Jatropha* genus has its origin in Latin, in
207 which *iatrós* means "doctor" and *trophé* "food", suggesting its medicinal properties
208 [31]. According to Sabandar et al., (2013) [32], several species of *Jatropha* have been
209 described especially in folk medicinal uses to cure stomachache, inflammation, leprosy,

210 dysentery, anemia, diabetis, to treat ophthalmia, ringworm, ulcers, malaria, skin diseases,
211 bronchitis, asthma and as an aphrodisiac. Pinhão-Bravo is an endemic Caatinga species
212 occurring exclusively in this biome. It is an easy to cultivate perennial shrub with a size
213 less than 5m in height [31; 11]. The stem is aerial, of the trunk type and branched. The
214 leaves are alternate, complete, with parallellobular ribs. The leaf is light green, there is
215 hair on both sides of the leaf and on the petiole. Terminal inflorescence is classified as
216 cimosa. The fruits are schizocarp type, measuring around 28 cm in length and 21 in
217 diameter, have green color, simple, globose and dehiscent, with a longitudinal opening
218 after ripening. The seed is dark in color, with thick tegument and large endosperm. The
219 spread is sexual with the dried fruit having three explosive dehiscence that throws the
220 seeds up to 1.8 m away from the mother plant [33; 34].

221 Leal and Agra (2005) [8] reported that the oil extracted from the seed is used as
222 an animal purgative. Unlike other species of the genus *Jatropha*, the quality of the oil
223 extracted from the seed of *Jatropha mollissima* is still little reported in the literature,
224 especially in relation to the composition of fatty acids. According to Barros et al.,
225 (2015) [11], the mean oil content of Pinhão-Bravo is 18.3% w/w, with a higher content
226 of unsaturated than saturated fatty acids. Indeed, Linoleic (C18:2) and oleic (C18:1)
227 acids represent around 58-63 % and 17-19% of total fatty acids. It is important to note
228 that depending on the origin, the oleic and linoleic acid content may vary.

229

230 **6. Pequi** (*Caryocar brasiliense*)

231 This kind of tree is from Caryocaraceae family, and in the Brazilian northeast it
232 can occur in the Caatinga biome transition regions with Amazon, Cerrado and Atlantic
233 Forest biomes, being found in the states of Minas Gerais, Maranhão and Piauí [20; 35].

234 Pequi is an indigenous word which means “covered with thorns”, due to the prickly
235 endocarp of its fruit [36].

236 Pequi tree is an arboreal plant (8 to 12 m), that has gray bark, thick and crooked
237 branches. The leaves are composed, opposite and with leaflets covered with hair. The
238 flowers (8 cm) are bisexual and pentamerous. The roots are deep pivoting (axial) type.
239 The fleshy fruit is of drupa type, containing from two to six putamens inside, which are
240 made up of seeds strongly linked to the rigid and spiny endocarp. The mesocarp is
241 bulky, yellowish and oleaginous and the epicarp is light green [20]. Its considered semi-
242 deciduous, as it presents partial loss of foliage in the dry period. The main form of
243 propagation is through its seeds. However, the pequi cultivation is limited due to the
244 presence of dormancy in the seeds. Extractivism is the main form of exploitation.

245 The dormancy of the pequi seed is twofold (physical or cutaneous and
246 physiological). The physical form of dormancy is caused by the stiffness of the
247 endocarp, while the physiological one is caused by biochemical inhibitors present in the
248 embryo. This physiological characteristic of seeds makes propagation difficult, causing
249 low germination rate. It is necessary to perform dormancy breaking techniques to
250 optimize germination.

251 Although the extractivism of wild specimens is the main way of obtaining the
252 fruit and seed, asexual propagation techniques, such as grafted seedlings, have been
253 used in order to domesticate the species, obtain good quality seedlings and expand
254 commercialization [20; 37; 38]

255 It is a species that has been widely explored due to the high oil content present in
256 both pulp and seed core, which reaches around 70.16 % w/w. The oil from the seed
257 mainly contains palmitic (34.4%) and oleic (56.1%) acids. Pequi oils (pulp and seed)
258 have great economic relevance for local communities, being used as cooking oil and

259 replacing butter [36]. The oil can be used for the manufacture of sweets, ice cream and
260 liquors, in addition to having applicability in the pharmaceutical, cosmetic and lubricant
261 industries. Although this species has great economic potential, it is important to note
262 that the destruction of native forests, the growth of agricultural frontiers and the
263 extraction of fruit were factors that contributed to putting Pequi at risk of extinction
264 [20].

265

266 **7. Oiticica** (*Licania rígida* Benth)

267 From Crysoalanaceae family, this plant is present in the riparian forests of the
268 Caatinga found near intermittent rivers of Brazil northeastern from the watersheds of
269 Piauí, Ceará, Rio Grande do Norte and Paraíba. In this way, the Oiticica have great
270 value in the preservation of riverbanks and temporary streams. The tree can reach up to
271 20m in height, the thick trunks have a branch close to the ground, the yellow flowers
272 branch in the bunches and the fruit has an ovoid shape measuring between 4 and 6 cm in
273 length. Its leaves are perennial, thick, rough and covered with thick cuticles. These
274 foliage characteristics are adaptations to drought that prevent excessive water
275 evaporation [39].

276 The exploration of the Oiticica is exclusively extractivist. The production of
277 native specimens does not occur on a regular basis, and can happen once in many years,
278 with some plants bearing fruit and others not. The average annual production of a 10
279 years old tree is approximately 30 kg of almonds, while in grafted plant orchards, the
280 production is 75 kg and can reach 100 to 200 kg if the pest control is done effectively
281 [20].

282 Oiticica oil is extracted from the almond seed that can be found in the ripe
283 fruit. The oil extraction yield can easily exceed 50% w/w_{dry}, with some variations

284 observed depending on the fruit's maturity level, genetic variability, and conservation
285 status [39; 40]. Nowadays, Oiticica oil is not considered an edible oil. It is mainly being
286 used in the production of paints, varnishes, enamels, soap industries with some research
287 in its application as biodiesel raw material [41]. Oiticica oil is usually applied in
288 varnishes due its fatty acid composition that contains high levels of conjugated
289 polyunsaturated fatty acids like α -Eleostearic acid (16.9%) and Licanic acid (43.2%).

290

291 **8. Discussion**

292

293 **8.1. Oil content, Fatty acid composition, additional bioactive compounds and** 294 **oleochemistry potential**

295 The productiveness and applicability of oil from plants depends on several
296 factors, such as seed oil content its properties and fatty acid composition. Examining
297 the seed oil contents and properties, as shown in Tables 1, it is possible to have a first
298 glimpse on the performance of the plants analyzed as oleaginous sources.

299 In this sense, Pequi demonstrates the highest potential as edible oil source,
300 being followed by Oiticica. However, more research regarding Oiticica oil application
301 for human consumption would be required, but until now, Oiticica oil is not considered
302 as an edible oil, probably because of its high oxidability, being apply to manufacture
303 varnishes, to coat containers for food, beverages, and medicines [49]. Despite the high
304 amount of oil, this percentage may vary between samples according to different
305 maturation degrees and fruit storage conditions. For instance, De La Salles et al.,
306 (2010)[46] reports a yield of oil extraction from Licuri Kernel of 39%, while Iha et al.,
307 (2014) [50] and Crepaldi et al., (2001) [51] shows 50% and 49.2%. These differences

308 also can be attributed to the use of fruits from different locations, being collected in the
309 states of Bahia and Maceió.

310 Due to structural diversity, fatty acids are extensively used as feedstocks for
311 food applications and the oleochemicals industry for the manufacture of soaps,
312 detergents, lubricants, coatings, and cosmetics among other specialty products [52].

313 It is possible to observe that the oilcrops listed above have distinct fatty acid
314 compositions (Table 2). Among them, Licuri oil is the only one that has more saturated
315 than unsaturated fatty acids in its composition, and one has to take some care regarding
316 its ingestion to obey the medical guideline recommendations for saturated fatty acids,
317 the intake of which should not exceed 10% total daily energy [55]. On the other hand,
318 Licuri oil is rich in the medium chain lauric acid and it could be an interesting oil source
319 for the oleochemical industry and for the obtention of lipid-based formulations with
320 various applications in pharmaceutical products and cosmetics [56; 57; 58]. So far,
321 coconut and palm kernel oils are the main oil sources for these applications [57].

322 These oils with medium chain saturated fatty acids are particularly attractive
323 because they are less sensitive to oxidation and they allow the synthesis of various
324 esters and mixtures of esters with peculiar dispersion properties when mixed with water
325 [58]. It was already proposed that Licuri oil, because of its lipophilic adjuvant and
326 hydrating characteristics, could be used in cosmetics in replacement of traditional oils
327 like sweet almond oil [59]

328 All the other oils of Caju, Favela, Pinhão-bravo and Pequi have a more
329 unsaturated fatty acid profile and seem more adapted to nutrition. Favela and Pinhão-
330 bravo oils are rich in the essential linoleic fatty acid, which has vital functions in the
331 structure of the cell membrane and in metabolic processes. Linoleic acid can be
332 metabolized into arachidonic Acid, a 20-carbon polyunsaturated fatty acids which is the

333 precursor of eicosanoids [60]. The increase of dietary intake of linoleic acid is
334 associated with a reduced incidence of cardiovascular diseases (mainly coronary artery
335 diseases) and of new onset metabolic syndrome or type 2 diabetes. However, high
336 quality clinical trials are needed to assess both the actual amplitude and the underlying
337 mechanisms of the health effects related to dietary intake of this essential fatty acid.
338 Nevertheless, these types of oils, are like rapessed oil, are more sensitive to oxidation
339 and must be processed with caution.

340 Caju and Pequi oils are richer in oleic acid which also provides nutritional
341 benefit and affords oxidative stability to the oil, that like corn, soybean and sunflower
342 oil that enables the use in cooking processes that involve high temperatures [61].
343 Among various functions, the intake of oleic acid elevates circulating levels of the
344 endogenous lipid mediator ethanolamide oleoylethanolamide (OEA) that plays a role in
345 modulation of lipid metabolism and energy intake in humans [62].

346 Therefore, a great diversity of fatty acids that can be found in exotic Brazilian
347 plants. Special attention needs to be given to Oiticica oil, for containing conjugated fatty
348 acids like α -Eleostearic and Licanic. α -Eleostearic Acid is a C18 ω -5 unsaturated fatty
349 acid with three conjugated double bonds (18:3 Δ 9 cis, 11 trans, 13 trans) while Licanic
350 acid is a keto derivate from α -Eleostearic Acid with an oxo (keto) group at the ω -15
351 carbon [63]. This fatty acid can be used for making resins [64]. Besides having
352 industrial applications in varnishes and paints, Eleostearic acid has been documented to
353 have anticancer properties [65]. Others conjugated fatty acids like conjugated linoleic
354 acids (CLA) have been receiving more attention for their antioxidant, antiobesity,
355 anticarcinogenic, antiatherogenicity, and antidiabetic activities [66].

356 The conjugated trienoic α -Eleostearic acid (9c,11t,13t-octadecatrienoic acid) is
357 well known for its high levels in Tung oil (up to 70% of total fatty acids) extracted from

358 *Aleurites fordii* seeds and used in Chinese lacquers because of its drying or siccative
359 properties [67; 68]. Licanic acid (4-keto-9c,11t,13t-octadecatrienoic acid) is a keto
360 derivative of α -eleostearic acid. Furthermore, the conjugated triene present in α -
361 eleostearic acid constitutes an intrinsic chromophore, which confers strong UV
362 absorption properties to this fatty acid ($\lambda_{\text{max}}= 272$ nm) and the triglycerides and
363 phospholipids in which it can be esterified. These properties were important for the
364 recent development of spectrophotometric assays for testing antioxidants such as the
365 Conjugated autoxidizable triene (CAT) assay [69], and for measuring lipase [49, 70 and
366 71]; and phospholipase activities [72]. Thus, the peculiar fatty acid composition of
367 Oiticica oil offers a great potential for various applications in health and oleochemistry.

368 Besides oil fatty acid profile, it is also worth paying attention to the bioactive
369 compounds that can be found in the oil and in the unsaponifiable matter, such as
370 vitamins and sterols, among others [73]. Bioactive substances present in plants have
371 become popular as complementary or alternative therapeutic agents to manage and/or
372 treat chronic diseases [74]. Some authors have been using pressurized fluid to extract
373 lipids without (or with minimal) degradation/decomposition of valuable bioactive
374 compounds, such as vitamins, sterols, and fatty acids, among others [17; 75]

375 For instance, Tawa et al. 2015 [76] reported that cashew oil can produce
376 around 1.64 mg/g of unsaponifiable matter and recently Zanqui et al., 2020 [17] showed
377 the route to obtain 18-19 mg of tocopherols and 60-70 mg of sitosterol per 100 g of
378 cashew oil by extraction performed using pressurized n-propane and 6% ethanol as
379 cosolvent. While Santos et al., (2020) [75] extracted favela oil using supercritical CO₂
380 to obtain an oil with 40.1 mg of tocopherols and 171 mg of β -sitosterol per 100 g of
381 favela oil.

382 Besides that, the use of an Pectinolytic enzymatic pretreatment in obtaining
383 Pequi pulp oil by cold pressing by [73] proved to be very efficient to obtain more
384 unsaponifiable matter (around 2.8%) that correspond, among others, to compounds
385 present in oils such as sterols, tocopherols and carotenoids. Thus, enzymatic pre-
386 treatments may help improving global biorefinery processes for a better valorization of
387 all compounds from Pequi pulp.

388 Likewise, the degree of fruit maturation also influences the amounts of
389 bioactive compounds extracted, like carotenoids. Oliveira et al. (2006) [77] found
390 values of 67.8 $\mu\text{g/g}$ of carotenoids in Pequi fruits collected from trees, 83.7 $\mu\text{g/g}$ in
391 fruits collected on the ground and 113.4 $\mu\text{g/g}$ in fruits collected on the ground after
392 natural fall and stored for 3 days at room temperature. Conversely, carotenoid losses
393 due to degradation after oil extraction, such as those caused by light, can occur. The
394 main carotenoids identified in Pequi oils were zeaxanthin, β -cryptoxanthin, and β -
395 carotene.

396 Regarding Licuri oil, the presence of additional bioactive compounds has not
397 been documented. However, Paula Filho et al., 2015 [78] studied the nutritional
398 composition of Licuri kernel, from which the oil is obtained, and they showed the
399 presence of α -carotene, β -carotene, β -cryptoxanthin, α -tocopherol, α -tocotrienol, β -
400 tocopherol, β -tocotrienol, γ -tocopherol and γ -tocotrienol. No data for Oiticica and
401 Pinhão-Bravo seed was found, reinforcing the need to better characterized these
402 bioresources for their potential application.

403

404 **8.2. Products from Brazilian semi-arid ecosystem: retrospective and novel**
405 **perspectives**

406 Recently, the European Commission (2018) defined the Bioeconomy and
407 circular bioeconomy (CBE) concepts to cover the production of several renewable
408 biological resources and their conversion to various high-value bio-based products such
409 as food, feed, biochemicals, and bioenergy [79]. The concept promises to mitigate the
410 effects of climate change while providing a renewable carbon source (biomass) as well
411 as creating business, employments and opportunities, especially in the rural areas. In
412 order to fulfill these expectations, the biorefinery concept plays a key role to optimize
413 the conversion of biomass and to achieve the goals set for CBE [80]. This concept led
414 many countries to develop integrated biorefineries [81]. The key to the sustainability of
415 chemical production processes is the feedstock. For bulk-chemicals the feedstock
416 contributes to nearly 70-80% of the production cost. However, to have a higher
417 relevance today these processes needs an environmentally friendly approach and the use
418 of a sustainable feedstock is an essential pre-requisite for future bulk-chemical
419 production processes [82]. There is still a huge gap between the expectations and the
420 actual performance of biorefineries circularity. The definitive roles of stakeholders –
421 local and international government agencies, the academic community, and private
422 companies – as well as their inter-relationships remain to be clarified which necessitates
423 systematic and comprehensive investigations. Policy frameworks and incentive systems
424 need to be aligned with the most recent scientific outcomes and relayed accordingly to
425 the concerned private sectors, which in turn, initiate the deployment of these
426 innovations into effective practice, and later on provide immediate feedback regarding
427 possible areas of improvement [80].

428 The world's agriculture and oil industries use only a few species. Some of
429 these species have been known for centuries, but there is a growing interest in
430 alternative oil sources from tropical floras [83; 84]. Thus, it is necessary to search for
431 new oil crops with oleochemical potential in a sustainable way, minimizing
432 environmental impacts due the exploration. In this context, information regarding the
433 potential of renewable oil sources from Brazilian semi-arid ecosystem (Cattinga) can
434 open doors to news discoveries and applications. The valorization of this biomass may
435 suggest new models of sustainable biorefinery with biological conversions including
436 microbial biocatalysis, enzyme biocatalysis, hybrid processes, and others [82]. The six
437 plants species from Cattinga investigated here show potential for the production of new
438 oleochemicals; They comply with several of the 12 principles of green chemistry such
439 as a production based on a renewable feedstock, with a low level of potential hazards
440 and with a generation of substances with low toxicity. Because of their bio-based
441 nature, products obtained using natural oils and fats are often biodegradable;
442 furthermore, the CO₂ generated from their degradation can be incorporated into next
443 year's crop, and they are likely to be nearly CO₂ neutral [85]. The biorefinery concept
444 implies an integrated process in which all the components that are included in the
445 biomass are utilized as raw material [82; 86]. With respect to residues from vegetal
446 lipids extraction, its worthy to mention the potential application of the cake generated in
447 the end of the process, which can be used as substrate for microbes in a submerged and
448 solid state fermentation processes. Several enzymes as biocatalysts can be produced
449 using these processes and this includes the lipases that can be used for the
450 biotransformation of the oil previously extracted [80; 87; 88]. Also, the cake can be
451 used in animal feed as well as in human foods. Cavalcanti et al., 2009 [89] have shown
452 for instance the functional properties of the delipidated Favela seed kernel proteins, that

453 can be used in elaborated foods that require high solubility of ingredients, high oil
454 emulsification performance and also modification of food texture and flavor.

455 Due to climate changes, it is expected that plants and derived products from the
456 Brazilian semi-arid ecosystem will have a greater sustainability than those from current
457 temperate regions. Among the oil-crops produced in Caatinga and reviewed here, only
458 Cashew nut, Pequi, Licuri and Oiticica are entering in the official statistics of the
459 Brazilian government (Table 3; retrospective between 2014 and 2018) [7], showing how
460 overlooked are Favela and the Pinhão-Bravo. Future perspective for these raw materials
461 depends on the correct retrospective to emphasize the need for sustainable exploration,
462 since they are important species for the biome. For instance, the severe decline of Pequi
463 and destruction of its populations due to land degradation and deforestation contributed
464 to making its logging illegal in some Brazilian States [90]. On the other hand some
465 species mentioned here can play a role in the restoration of degraded areas, like the
466 Licuri palm tree, which can act in the maintenance of other species by hosting around
467 30 species of epiphytic plants mainly from the *Orchidaceae*, *Bromeliaceae* and
468 *Polypodiaceae* families [91]. Favela and Pinhão-Bravo can also be easily used in this
469 sense, by having high dissemination properties and full adaptation to the conditions of
470 the area [92]. Technological developments and assessment of biorefinery models should
471 be based on the regional knowledge gained from Brazilian semi-arid ecosystem,
472 including geographical and seasonal variations in these various types of oil crops, as
473 well as the involvement of local communities.

474

475 **9. Conclusion**

476

477 Brazilian Northeast Caatinga Forest has a rich vegetal diversity, among which
478 species like Cashew nut, Favela, Licuri, Pinhão-Bravo, Pequi and Oiticica stand out as

479 potential oilseeds crops, due to their high oil contents, fatty acid composition and
480 proprieties. However, only a small fraction of this biodiversity is known and used,
481 probably due to climatic conditions and also because this region historically
482 concentrated most of the rural poverty in Latin America. A sustainable management of
483 these bioresources using a biorefinery strategy could help improving the valorization of
484 these oil crops, contributing to biodiversity conservation and at the same time, to the
485 income of local populations based on nutritional and environmental value, as well as
486 process developments. The oleochemistry potential from Brazil northeastern exotic
487 plants can be one of the sustainability tools for establishing local biorefineries, a circular
488 bioeconomy improving the quality of life of local population and for serving a
489 consumer market eager for new ecofriendly products.

490

491 CONFLICT OF INTEREST

492

493 The authors declare no conflict of interest.

494

495 ACKNOWLEDGMENTS

496

497 The authors are grateful for the financial support by the Coordenação de
498 Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES), specially for the
499 scholarships provided for Milena Chagas Lisboa (PROSUP - 88882.365551/2019-01,
500 PDSE 41/2018 - 88881.361582/2019-01) and Flavia Michelle Silva Wiltshire (PROSUP
501 88882.365583/2019-01).

502

503 AUTHOR CONTRIBUTIONS

504

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506 Wiltshire: collection of data, writing of manuscript; R. L. Souza: analysis of data; A.T.
507 Fricks: analysis of data; C. Dariva: writing of manuscript; F. Carrière: analysis of data,
508 writing of manuscript; Á. S. Lima: conception of the work, analysis of data; C. M. F.
509 Soares: conception of the work, analysis of data, writing of manuscript. All authors
510 have approved the final version of this article.

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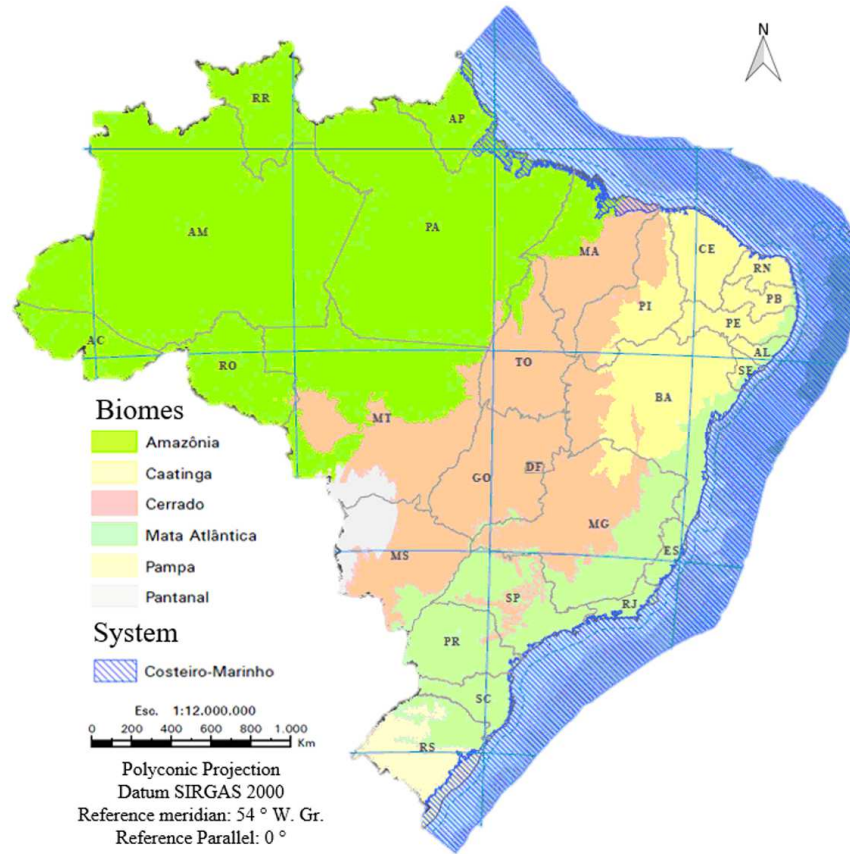
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755 FIGURE LEGENDS

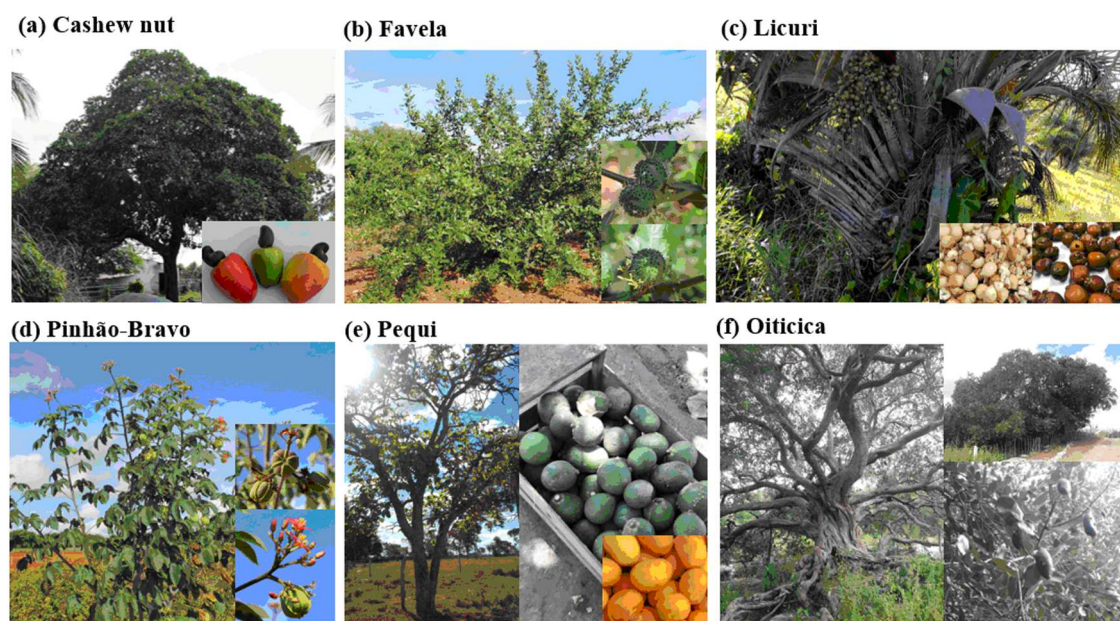
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757 **Figure. 1.** Brazilian Biomes Map. (Source: IBGE, 2019)



758

759 **Figure 2.** Representative species of the Brazilian Caatinga that can be used as a source
760 of oil. (a) *Anacardium occidentale* L.; (author original photo collection) (b) *Cnidoscolus*
761 *quercifolius* Pohl (author original photo collection); (c) *Syagrus coronata* (Mart.) Becc.
762 (author original photo collection); (d) *Jatropha mollissima* Pohl Baill (author original
763 photo collection);(e) *Caryocar brasiliense* (author original photo collection); *Licania*
764 *rígida* Benth (author original photo collection).



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767 TABLES

768

769 Table 1. Extraction techniques, yields and physical-chemical parameters of vegetable oil extracted from Caatinga oil crops. Yield of
770 extraction and physicochemical oil parameters data are respectively from: Cashew nut [42; 43], Favela [44; 45], Licuri [29; 46], Pinhã-
771 Bravo [11, no data available], Pequi [47; 48] and Oiticica [41].

| FeedStock | Fruit Part | Yield of extraction | Extraction technique | Acid value (% FFA, as oleic acid) | Iodine value (g of I₂ per 100 g of oil) | Saponification (mg of KOH/g of oil) | Peroxide value (meq O₂/kg of oil) |
|---------------------|-------------------|----------------------------|-----------------------------|--|---|--|---|
| Cashew nut | Nut kernel | 33.1 ± 0.6 | Soxhlet, Hexane | 2.44 | 87.63 | 159.9 | 4.087 |
| Favela | Seed | 33.5 ± 1.18 | Cold press | 4.33 | 109.79 | 121.28 | 6.99 |
| Licuri | Endosperm | 49.2 ± 0.08 | Soxhlet, Hexane | 1.4 | 18.5 | NA | NA |
| Pinhão-bravo | Seed | 18.25 ± 1.63 | Soxhlet, Hexane | NA | NA | NA | NA |
| Pequi | Pulp | 70.16 ± 1.18 | Boiling water | 5.4 | 50.0 | 206.8 | 7.94 |
| Oiticica | Seed | 57.0 ± 4.24 | Electric press | 1.52 | 95.4 | 194.0 | NA |

772 NA: not available

773 **Table 2.** Fatty acid composition (% w/w of total fatty acids) of vegetable oils determined by gas chromatography coupled to mass
 774 spectrometry (GC-MS). All the structures are available at pubchem and chebi data bases [53; 54].

| Fatty Acid | 2D Structure | Cashew nut [17] | Favela [44] | Licuri [50] | Pinhão-bravo [11] | Pequi [36] | Oiticica [41] |
|--|--------------|-----------------|-------------|-------------|-------------------|------------|---------------|
| Caprylic (C8:0) | | - | - | 13.00 | - | - | - |
| Capric (C10:0) | | - | - | 8.00 | - | - | - |
| Lauric (C12:0) | | - | - | 48.00 | - | - | - |
| Myristic (C14:0) | | - | 0.30 | 14.00 | - | 0.20 | - |
| Palmitic (C16:0) | | 9.37 | 16.63 | 5.00 | 11.50 | 34.40 | 5.00 |
| Stearic (C18:0) | | 9.87 | 7.21 | 2.00 | 8.00 | 3.10 | 8.30 |
| Oleic (C18:1) | | 66.68 | 20.13 | 7.00 | 18.00 | 56.10 | 10.60 |
| Linoleic (C18:2) | | 12.05 | 54.39 | 3.00 | 60.50 | 5.20 | 3.00 |
| α -Eleostearic (C18:3 9c.11t.13t) | | - | - | - | - | - | 16.90 |
| Licanic (C18:3 4-keto;9c.11t.13t) | | - | - | - | - | - | 43.20 |
| Others | - | 2.03 | 1.34 | - | 2.00 | 1.00 | 10.30 |

775

776 Table 3. Native species production data expressed in Brazilian local currency, reais (R\$) [7].

| Application | | Food | | | | Oilseeds | | | | |
|---------------------------|---------------|-----------------------|---------------|---------------------|---------------|--------------------|---------------|--------------------|---------------|--------------------|
| Product | | Cashew nut (chestnut) | | Pequi (fruit) | | Licuri (coconut) | | Pequi (almond) | | Oiticica (seed) |
| Years\Productivity | Amount | Value | Amount | Value (1.000 | Amount | Value | Amount | Value | Amount | Value |
| | (t) | (1.000 R\$) | (t) | R\$) | (t) | (1.000 R\$) | (t) | (1.000 R\$) | (t) | (1.000 R\$) |
| 2018 | 1411 | 4189 | 21495 | 18521 | 1078 | 1562 | 765 | 2986 | 6 | 6 |
| 2017 | 1421 | 4571 | 21915 | 21287 | 1151 | 1502 | 832 | 3098 | 6 | 7 |
| 2016 | 1775 | 4894 | 17305 | 14766 | 3787 | 3741 | 1471 | 4042 | 7 | 7 |
| 2015 | 2160 | 4670 | 18866 | 14236 | 4072 | 4039 | 2228 | 4897 | 15 | 9 |
| 2014 | 2489 | 4386 | 19241 | 14589 | 3744 | 3974 | 1381 | 4059 | 16 | 10 |

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