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Potential Crops for Biodiesel Production in Brazil: A Review

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Abstract: Recently biodiesel has been receiving increasing attention as an alternative fuel due to its environmental benefits. Also, it is derived from renewable sources which are considered as strategic opportunities to favor environmental sustainability, to improve the population's quality of life and to promote the development of more efficient and equitable economic systems. Since the petroleum crises in 1970s, increasing prices rapidly and uncertainties concerning petroleum availability, a growing concern of the environment and the effect of greenhouse gases during the last decades, has revived more and more interests for using the vegetable oils as a substitute of fossil fuel. All vegetable oils referred as fixed oils or triglycerides can be used as raw matter for biodiesel production. This is a promising activity in Brazil due to the potential growth of physic nut, sunflower, soybean, castor bean, African palm, babassu, cotton, peanut, linseed, macauba, pequi, buriti, sesame, canola and other. The production and commercialization of biodiesel in Brazil could provide an opportunity to diversify energy and agricultural activity, reducing dependence on fossil fuels and contributing to economic growth in a sustainable manner. This article is a review on potential crops for biodiesel production in Brazil, emphasizing aspects as the best planting dates, the regions appropriated for cultivation, the crop requirements, the social and economic importance of the crops and the recent studies about their use as raw matter for biodiesel production.

Key words: Vegetables oils · Biofuel · Sustainability · Crops

INTRODUCTION

The crescent concern with environmental issues, the fast decrease of fossil fuels reserves around the world and the increase in price of them have motivated the use of vegetable oils for producing alternative fuels. Despite the need to reduce the natural viscosity and to improve the ignition quality of these oils during their conversion, the resultant biodiesel has been shown to give engine performance generally comparable to that of conventional diesel fuel, while reducing engine emissions of particulates, hydrocarbons and carbon monoxide [1]. The lowest clouding point, high cetane number and high flash point of biodiesel are also important advantages of this fuel [2]. Because of these features, biodiesel is non-toxic, biodegradable and recycled [3].

All vegetable oils referred as fixed oils or triglycerides can be used as raw matter for biodiesel production, which is a promising activity in Brazil due to the potential growth of physic nut, sunflower, soybean, castor bean, African palm, babassu, cotton, peanut, linseed, macauba, pequi, buriti, sesame, canola and other [4,5]. The production and commercialization of biodiesel in Brazil could provide an opportunity to diversify energy and agricultural activity, to reduce dependence on fossil fuels and to contribute to economic growth in a sustainable manner [6].

The National Programme for the Production and Use of Biodiesel (PNPB) is an Interministerial Programme of the Brazilian Federal Government with the objective of implementing, in a technically and economically sustainable fashion, the production and use of biodiesel, focusingon social inclusion and regional development through the creation of employment and income. The principle directives of PNPB are to implement a sustainable programme, to promote social inclusion, to guarantee competitive prices, quality and supply, to produce biodiesel from different oleaginous plants in diverse regions [7].

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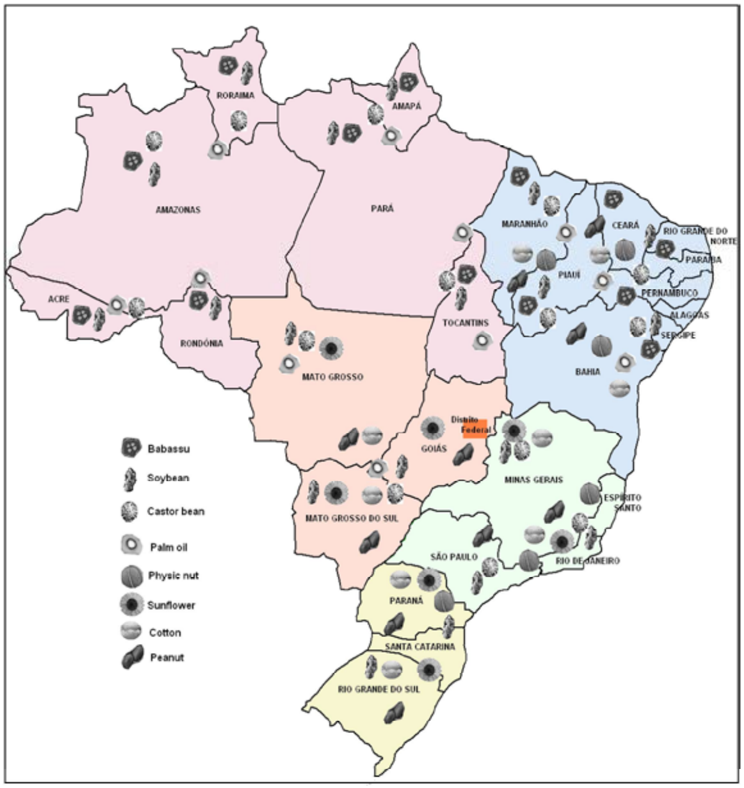

Fig. 1: Brazil's potential for production of oleaginous crops

Crop growth is influenced by several factors, as water, nutrients, soil and weather. Many different high value oil crops can be cultivated in Brazil due to its diversity of biomes (Fig. 1). Some of these crops are native of Brazil and during many years their production was extractivist. But researchers have been demonstrating the high potential of them for commercial planting and biodiesel production [8-11].

Physic Nut: The interest in using physic nut (*Jatropha curcas*) as a feedstock for the production of biodiesel is rapidly growing. The oil produced by this crop can be easily converted to biofuel, which meets the American and European Standards. Additionally, the press cake can be used as a fertilizer and the organic waste products can be digested to produce biogas. The plant itself is believed to prevent and control soil erosion or can be used as a living fence or to reclaim wasteland. Physic nut is still a wild plant, which can grow without irrigation in a broad spectrum of rainfall regimes, from 250 up to 3000mm per annum. Furthermore, this crop is reported to have few pests and diseases, but this may change when it is grown in commercial plantations with regular irrigation and fertilization [12].

Fig. 2: Physic nut crop

Physic nut (Fig. 2) has its native distributional range in Brazil, Mexico, Central America, Bolivia, Peru, Argentina and Paraguay, although nowadays it has a pantropical distribution with more than 170 seed provenances [13].

The average oil content of dry seed on mass basis is 34.4% and the potential yield of this crop ranges from 1.5 to 7.8tdryseedha^{-1}year^{-1}[12].

In Brazil, the agroclimatic zones suitable to grow the physic nut were identified for the State of Paraná

Fig. 3: Sunflower seeds and flower

(South Brazil) through the characterization of regions with low climatic risk for this crop. Based on historical series and on a Geographic Information System (GIS) it was evident that the expansion of the physic nut in the State of Paraná is viable [14]. In another work, the minimum lethal temperature for seedlings of the oil seed plant was determined, aiming at supporting the expansion of physic nut crop in Southern Brazil as an alternative for biofuel production. It was concluded that the minimum lethal temperature for this crop is between -3°C and -4°C [15].

The viability of physic nut crops in the State of Bahia (Northeast Brazil) was also evaluated. It was concluded that Bahia presents 20.9% of suitable areas for cultivating this plant, 63.9% of marginal areas due to water deficit and 15.2% of inapt areas [16]. Based on the crop requirements, the physic nut cultivation was considered viable as an alternative crop for the Northeast semi-arid and for the Southeast of Brazil [13].

Since the biodiesel production from physic nut has become a booming business, there is the need of more studies about the agroclimatic zones suitable to grow it in Brazil and about the ideal cultivation systems for this crop mainly considering irrigated and dryland agriculture.

Also, more researches are necessary about the properties of physic nut oil. Recent studies indicated that its quality is dependent on the interaction of environment and genetics, presenting a very wide range values for the free fatty acids, unsaponifiables, acid number and carbon residue [12].

Sunflower: The sunflower (*Helianthus annuus*) is an annual plant and is one of the four most important oilseed crops in the world. The nutritional quality of its edible oil ranks among the best vegetable oils in cultivation [17]. From sunflower, almost all is used. Its stem can be used as acoustical covers, its flowers and seeds can be used as human food and its oil can be used as biodiesel feedstock [18]. Sunflower seeds have oil content of between 38 and 48% on dry weight basis. The potential yield of this crop ranges from 0.5 to 1.9 tha^{-1}year^{-1} [19].

Sunflower (Fig. 3) is grown in many semi-arid regions of the world from Argentina to Canada. It is more tolerant to low temperatures. Sunflower can grow in a wide range of soil types from sands to clays [20].

The best planting dates for sunflower in South Brazil were determined by studying meteorological data and the crop requirements. It was concluded that the most suitable month for planting sunflower in South Brazil was September [21]. Also, the water requirements of sunflower were compared with climatic conditions in order to determine better planting dates in the State of Paraíba (Northeast Brazil). It was concluded that the most suitable planting time of sunflower on State of Paraíba would be through March to April. But there are some microregions where this production would be not appropriated [22].

In another study, the possible sunflower relative yield losses were estimated for 36 different sowing dates for three distinct areas in State of São Paulo (Southeast Brazil). The results showed that in the Piracicaba and Ribeirão Preto regions the risk of losses were minimized in sowing between October and December, when less than 10% of yield losses occurred in 90% of the evaluated years. In the Manduri region almost 85% of the evaluated years had crop yield losses lower than 10% when sowings were made between September and January [23].

Considering the climatic conditions, the south region of the State of Minas Gerais (Southeast Brazil) is suitable for the cultivation of sunflower, being apt for two annual cultivations in the same piece land. In general, the sunflower as a rotation crop in the Southeast Brazil has been an alternative, since it is capable of be cultivated in irrigated and non irrigated lands in the period between harvests[24].

Sunflower oil does not have one fixed quality, but different qualities depending on weather conditions and on agricultural practices [25]. For this more researches are necessary about using sunflower crop as biodiesel feedstock, as well as, studies about more suitable methods, areas and dates for its cultivation in Brazil.

Soybean: Soybean (*Glycine max*), as well as its subproducts, is widely consumed as human food. It is rich in proteins, fatty acids and phytochemicals.

Fig. 4: Soybean seeds

Fig. 5: Castor bean seeds

Researchers have demonstrated that soybean isoflavones are associated with a lower risk of cancer [26]. The biodiesel production from soybean has been widely studied and the researches have been proven the potential of this crop for this purpose [27].Soybean has oil content around of 17% on dry weight basis and a potential yield between 0.2 and 0.4 $tha^{-1}year^{-1}$ [19].Actually, soybean (Fig.4) is cultivated worldwide attesting to the crop success and adaptability. This crop requires temperatures from 20 to 35°C and about 950 mm of water annually to produce maximum yields [28].

During the 1960s, soybean cultivation was concentrated in the three states of the Southern Region of Brazil: Rio Grande do Sul, Santa Catarina and Paraná. The agricultural zoning and some soybean production pointers were compared in the counties that are part of the significant production region of this crop in Rio Grande do Sul. Counties were grouped according to the yield, the production and the ratio of the soybean harvested area and the total county area. Results showed that there is a narrow relation among the groups formed by the three variables analysis [29].

During the last decades, the expansion of this crop to the Brazilian central cerrado region took place, once varieties had been developed that were adapted to low latitudes. The Southern region is characterized by smallholder farmers, mostly organized in cooperatives, whereas the central region is characterized by large holdings, with very high levels of mechanization and mostly organized in large private groups. In addition, climate is more stable in Central Brazil. The latest soybean expansion has taken place in the Northern Legal Amazon. Currently, soybean production in the North represents only a small fraction of the planted area [30].

In 2006 soybean was dominating as the primary material for biodiesel in Brazil. But this situation is gradually changing due to the environmental sustainability goal of the Brazilian Biodiesel Program (PNPB). Soybean is an oil crop cultivated on large scales and in monoculture. It requires the clearing of extensive areas of land, with eventual loss of biodiversity and the use of pesticides, that may contaminate the soil and water. The predominance of soybean may also jeopardize biodiesel's social and energetic aspects of sustainability, since job creation for soy-based biodiesel has been estimated to be over 100 times smaller than that of castor bean in Brazil [7].

Castor Bean: Castor bean (*Ricinus communis*) is belongs to Euphorbiaceae family, common to all the warm regions of the world. It is a fast growing fibrous nonwood plant native to eastern Africa, especially the Ethiopian area. Castor bean (Fig. 5) is grown as an annual in temperate zones and as a perennial in the tropics. This crop is cultivated for its seeds, which contain up to 45% of a fast-drying natural oil rich in ricinoleic acid used mainly in medicines and industry. World annual production of castor is 1.1 million tons of seeds and its yield is around 0.7 $t\ ha^{-1}\ year^{-1}$. The main producers are India, Brazil and China. In Brazil this crop is cultivated in all regions [19,31].

Biodiesel obtained from castor oil has a lower cost compared to the ones obtained from other oils due to its solvability in alcohol transesterification occurs without heating [32]. The biodiesel produced from castor bean also satisfies the relevant quality standards without regard to viscosity and cold filter plugging point [33].

The best planting dates for castor bean were studied in State of Bahia (Northeast Brazil) by evaluation of the climatic risks associated with three different soils and the water deficit of the plant. It was concluded that the best planting dates for castor bean in State of Bahia are from November to December [24]. In a similar work, a simulation model and geoprocessing techniques were used for identifying the best planting dates, considering dryland agriculture, in Maranhão and Pernambuco States (Northeast Brazil). Based on the results, the best planting dates for castor bean in Maranhão are from January to February and in Pernambuco these dates are between January and April [34,35].

Another study was carried out in order to list the counties of Brazilian Northeast Region appropriated to castor bean crop and to determinate de best planting time. For considering a county appropriated for castor crop it needs: medium temperature between 20 and 30°C, altitude between 300 and 1500m and well drained soil. Plant time was choose in such way to make good use of the raining season but allowing harvest to happen into the dry season. Number of counties listed was 9 of them on Alagoas State, 189 on Bahia State, 74 on Ceará State, 12 on Maranhão State, 48 on Paraíba State, 47 on Pernambuco State, 42 on Piauí State, 28 on Rio Grande do Norte State and 3 on Sergipe State [36].

The spread of biodiesel plants has motivated the cultivation of castor bean in South Brazil. Twenty castor hybrids were tested and presented agronomic features and yields with potential for cultivation in this Brazilian region [37].

Castor bean requires a large amount of hand labor. It is therefore a suitable crop for the small-scale farming structures in Brazil. It can help to improve the living conditions of small farmers as well as supply environmentally friendly energy for multiple purposes. However, as long as new markets or utilization strategies are not acquired, the trade and export of castor oil may cause problems, as on the one hand the world market is relatively stable and on the other hand the price is so high that it will hardly replace other vegetable oils[38].

African Palm: The African palm or dendezeiro (*Elaeis guineensis*) presents high productivity and medium to long-term possibilities of replacing considerable amounts of petroleum derivatives [39]. The cultivation of African palm in areas of the Amazon Region that were deforested was proposed and, for an area ranging from 2 to 3.2 million hectares, the estimated oil production went from 77.5 to 124×10^6t [40].

Fig. 6: African palm and dendê walnuts

African palms give their first fruits 4 to 5 years after planting and production peaks between 20 and 30 years. Palm bunches weigh 15 to 25kg and contains 1000 to 4000 egg-shaped fruits (Fig. 6). Each hectare of African palm produces an average of 10t of fruits per year from which an amount of 3000 to 6000kg of oil is obtained, this is, oil content around of 20% on dry weight basis [41].

The African palm is now one of the major economic crops in a large number of countries, which triggered the expansion of plantation area around the world. Also, the renewable/fossil energy relation for oil palm biodiesel is higher in comparison with the one attained for other crops. The main reason for this is the high productivity of the oil palm, which is nearly eight times higher than the other plants. The culture of African palm also produces a larger amount of biomass, which aggregates value to the industrial process and to the agricultural production, with the possibility of using it as fuel for steam and electricity generation [42].

In Brazil, large plantations of African palms exist in the States of Pará, Amazonas, Amapá and Bahia (North and Northeast regions). This culture requires about 2000 mm of water annually, temperatures greater than 24°C and deep soils [43].

Some preliminary results of climatic risk zoning for African palm plantation in the State of Pará (North Brazil) were described. This Brazilian State is the major African palm producer in Brazil and concentrates more than 80% of this crop [44]. Two approaches of zoning were used: the agroclimatic zoning and the climatic risk zoning. For these analyses, the time period for the sexual differentiation of the floral bud, was considered as the crop's critical phase in relation to water deficit.

Fig. 7: Babassu tree and fruits

The results obtained were used for spatial analyses by using a GIS to obtain a final map. The main results were an African palm agroclimatic aptitude map for the State of Pará with indication of the areas classified as good, moderate and restricted and the definition of four levels of climatic risk for the crop cultivation in the African palm plantation (with very low or without climatic risk, with small climatic risk, with moderate climatic risk and with great climatic risk) [44].

States of Bahia (Northeast) and Amapá (North) are also large producers of African palm. The Bahia Southeast has an exceptional diversity of soil and weather appropriated for the African palm cultivation, with an available area of 854,000 hectares [45].

Babassu: Babassu (*Orbignya phalerata* or *Orbignya oleifera*) is a palm tree (up to 20m in height), which is found naturally in Brazil and Colombia. The main products are fruits which are small coconuts that hang from bunches, 4 per tree per season, with about 20 coconut fruits each (Fig. 7). In terms of agricultural characteristics, the areas where this palm tree grows have a minimum insolation of 2400 annual hours and precipitation no less than 1700mm per annum [10].

The area of babassu in the Brazilian Northeast was estimated to be about 12 millions of hectares, with the State of Maranhão being the major producer. Around 140,000 tons of almonds are extracted from these plantations monthly [46]. The oil content of babassu almonds is around 66% [19]. Other Brazilian regions where this crop is found are North and Central. In Southeast only the State of Minas Gerais has an expressive area with babassu palms [46].

One key aspect in the exploitation of the babassu is the collecting and gathering system. There are no plantations of these palm trees, so the fruits have to be collected from natural woodlands by the indigenous population. In the case of Brazil, fruits are collected and broken. After, the kernels are sold to small dealers who sell them to the oil-extraction industries [10].

Several researchers have been investigating the biodiesel of babassu. Biodiesel was obtained by transesterification of babassu oil in anhydrous ethanol and methanol. The products obtained were characterized by physico-chemical and thermogravimetric analysis. It could be concluded that the properties of the two types of biodiesel (ethanolic and methanolic) are very similar when compared with diesel oil [47]. Also, the efficiency of the chromatographic methods was confirmed with the products of enzymatic transesterification of babassu oil with different alcohols, using lipozyme as catalyst [48].

Such kind of studies should be motivated in order to employ the potential of babassu as a plant oil source for biodiesel production.

Cotton: Cotton (*Gossypium spp*) is one of the most important economic fiber crops. There are more than 50 species. Of them, four species (*Gossypium hirsutum*, *Gossypium barbadense*, *Gossypium arboreum* and *Gossypium herbaceum*) are widely planted in 70 developed and developing countries, including the United States of America, China, India, Egypt and Brazil. It is estimated that more than 180 million people are associated with the cotton fiber industry that annually produces 20 to 30 billion dollars worth of raw cotton [49]. Cotton has oil content around of 15% on dry weight basis and potential yield ranging from 0.1 to 0.2 $tha^{-1}year^{-1}$ [19].

Blends of cotton oil soapstock biodiesel and diesel fuel can be used as alternative fuels in conventional diesel engines without any major changes. High calorific value and cetane number, low sulfur, low aromatic content and similar characteristics are advantageous of cotton oil soapstock biodiesel-diesel fuel blends [2]. Transesterification results showed that with the variation of catalyst, methanol or ethanol, variation of cotton biodiesel production was realized [50]. Also, cotton seed is non-edible oil, thus food versus fuel conflict will not arise if this is used for biodiesel production.

The cultivation of cotton (Fig. 8) had been increased in Brazil. Also, the promotion of appropriate politics and the development of modern exploration techniques are reducing environmental impacts and contributing for the maintenance of this crop as an important source income for Brazilian producers[51].

Fig. 8: Cotton plant

Fig. 9: Peanut flowers and seeds

A climatic zoning of the Northeast Region of Brazil for herbaceous cotton culture was carried through. The results were gotten through analysis of the water balance and average, maximum and minimum temperatures for meteorological stations located in 23 cities in the region. Two-thirds of the cities were considered apt for the herbaceous cotton culture [36].

Zoning for cotton crop and the best sowing time were also studied for identifying suitable areas in Northern Espírito Santo State (Southeast Brazil). For the determination of planting time and cotton zoning, plant requirements were compared to precipitation during rainy season and environmental factors such as temperature, relative humidity, topography and information obtained from "Natural Unit Map of North of Espírito Santo". Ten counties presented suitable conditions for cotton cultivation. Eight of them were classified as of restricted aptitude due to topography restriction and high relative humidity. Only two counties were classified as of preferential aptitude, where optimum conditions for cotton cultivation were found [52]. Climatic zoning for herbaceous cotton in the State of Mato Grosso (Central Brazil) was also carried out [53].

Systematized studies were done on cotton zoning to define the best sowing dates nationwide. It was observed that Brazil has 19 States producing cotton. From those, 14 have zoning already accomplished at municipal level, with uniform sowing dates for counties of each State. The sowing period in Brazil begins in the month of September and ends in the month of May [54].

Peanut: Peanut (*Arachis hypogaea*) is an important crop grown worldwide. It is an annual crop widely cultivated in warm climates and has short lived yellow flowers (Fig. 9). Most peanuts grown in the world are used for oil production, peanut butter, confections and snack products. Crude peanut seed oil has good potential as alternative diesel fuel. The seed contains 50% oil that may provide an inexpensive source of triglycerides for conversion to biodiesel. Crude peanut seed oil and its methyl ester have about 8.3 and 6% less heating value than that of petroleum diesel oil, respectively. Viscosity and density of methyl ester of peanut seed oil are found to be very close to that of diesel [55].

The potential yield of peanut crop ranges from 0.6 to 0.8 $tha^{-1}year^{-1}$ [19]. In Brazil, most of peanut production is allocated to the internal market, mainly in State of São Paulo (Southeast Brazil) and Northeast region [56]. But, the States of Goiás, Tocantins and Mato Grosso (Central Brazil), as well as the State of Minas Gerais (Southeast Brazil) are also producers of peanut [57].

In the Northeast Brazil, this unctuous plant has been cultivated in a traditional way in condition of unsprinkle crop, submitted to many risks made by weather variation. The effects caused by water deficit during 35 days in young plants of peanut were evaluated. The results showed that the water deficit reduced the plants growth, without stop. Young plants of peanut developed strategies to tolerate the environmental changes about water restriction, increasing the bioweight to the roots [58].

The best sowing time and suitable areas in State of Rio Grande do Norte (Northeast Brazil) were identified considering the peanut crop. In the east region of the State the best sowing period occurs between January 11 and 31. In the west region of the state the best sowing period ranges from March 21 to April 20 [59].

The agroclimatic indexes based on water balance and air temperature means were used for characterizating areas with different aptitudes for peanut crops in the watershed of high and medium São Francisco River (Minas Gerais, Southeast Brazil). Great part of the watershed showed restrictions for the crop due a high water deficit. However, irrigation can make possible the cultivation in these areas [60].

Other Crops: The biodiesel of linseed (*Linum usitatissimum*) has been studied worldwide. Experimental and theoretical studies have been investigated the biodiesel yield from linseed oil, the effects of its use in diesel engines and the effects of external factors, as temperature, injection pressure and other, on its performance [27,61,62]. Linseed is an important oilseed in the world. It is mainly grown in Canada, Argentina, America, China and India [63]. It has potential yield ranging from 0.6 to 1 tha^{-1}year^{-1} and oil content between 35 and 45% on dry weight basis [64]. In spite of its potential, linseed remains under-exploited in Brazil. The few plantations of this crop are found in the South Brazil, maintained by german and pole immigrants [65].

The macauba (*Acrocomia aculeata*) is a native fruit of the Brazilian Cerrado and is located mainly in the centre of the country, in particular, in the State of Minas Gerais (Southeast Brazil) [66]. This crop has potential to produce up to 30 t of fruits ha^{-1} year $^{-1}$, which present oil content between 23 and 34% on dry weight basis [67]. The macauba pulp oil presents, few weeks after fruit harvest, high content of Free Fatty Acids (FFA). For this, it is usually used to soap production. Two alternatives routes were compared for producing biodiesel from macauba pulp oil with 35% of FFA. The hydroesterification processes reached 78 and 22% of conversion in a small reaction time (60 minutes) with and without catalyst, respectively. The immobilized lipase has produced a superior conversion (85%) after 72 hours. Although the esterification time using lipase is very high, bioconversion appears as a cleaner technology to biodiesel production. Furthermore, the biodiesel presented lower viscosity and better quality due to low temperature of enzymatic reaction [9].

Pequi (*Caryocar brasiliense*) is the fruit of a tree popularly known in Central Brazil. The average oil content of pequi pulp on mass basis is 30% and the potential yield of this crop is around of 3.7 t ha^{-1}year^{-1} [67]. It contains carotenes, retinols, vitamin C and polyphenols. These compounds possess antioxidant properties preventing excessive free radical formation and modulating the genotoxicity of physical and chemical agents in the body [69]. Experiments were conducted in a pyrolysis batch reactor using pequi oil. The major products identified in the bio-oil were alkanes and alkenes [70]. The methanolysis of pequi was also studied. Activities of the tin and lead pyrone complexes were observed in the alcohol studies [71].

Buriti (*Mauritia flexuosa*) is also a native fruit of the Brazilian Cerrado and is located mainly in the centre and north of the country [72]. The average oil content of buriti on mass basis is 29% and the potential yield of this crop ranges from15 to 25 tof bunches ha^{-1}year^{-1} [73]. The sustainability of buriti biodiesel was analyzed as well as its use to enhance biodiesel has been investigated. The formation of alkanes, alkylcycloalcanes and alkylbenzenes during the catalytic hydrocracking of buriti oil where analyzed with good results [73,75].

Sesame (*Sesamum indicum*) is an economically important oil seed crop which is widely cultivated in many parts of the world, primarily in tropical and subtropical areas of the world, including India, China, Sudan, Burma, Tunisia, Egypt, Thailand, Mexico, Guatemala, El Salvador, Afghanistan, Pakistan, Bangladesh, Indonesia, Sri Lanka, Saudi Arabia and Turkey and has recently been adapted to semi-arid regions [76]. In Brazil, sesame (commonly known as gergelim) is an oilseed cultivated in all regions, having special importance in the Northeast region where it was introduced as an alternative to cotton. Sesame seeds are cultivated mainly for use in food industries and restaurants and for oil production [77]. Its oil content ranges from to 57 to 63% and its yield is between 0.5 and 1.0 t ha^{-1} year^{-1} [76,78]. Several studies investigated sesame seed as an alternative feedstock for the production of a biofuel and results supported that its methyl ester can be successfully used as diesel [76,79,80].

Canola oil is a low erucic acid containing between 40 and 48 % oil, which is now second largest oilseed crop after soybean. The yield of this crop ranges from 0.5 to 0.9 t ha^{-1} year^{-1} [19]. Transesterification of canola oil produces ester whose properties are comparable with those of conventional diesel fuels. It has also been reported that the lubricity of diesel fuel can be enhanced by 60% with the addition of 1vol% canola derived methyl ester. The enzymatic production of biodiesel from canola oil using immobilized lipase was also studied [81,82]. Canola (*Brassica napus*) has been cultivated in South Brazil as winter crop and has potential to be expanded to Central and Southeast Brazil [83,84].

CONCLUSION

Brazil has large diversity of oleaginous cultures that are cultivated and which have a high potential of producing biodiesel. Some of them were discussed in this work, but there are many others, as tucum, avocado, coconut and andiroba. Aiming to diversify the energy matrix, the Federal Government of Brazil has already established the insertion of biodiesel in the national fuel market with laws authorizing its use. This has motivated the investigation of new technologies and the characterization of biodiesel from native species and crops adapted at Brazilian regions. Results associated with these studies are lower production costs, increase of biodiesel yields and the possibility of the vegetable crops that at present are explored under an extractive approach acquire commercial attractiveness.

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